

AMRL-TR-65-125

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TOXIC HAZARDS RESEARCH UNIT

DESIGN AND CONSTRUCTION PHASE

J. D. MacEWEN

AEROJET-GENERAL CORPORATION

SEPTEMBER 1965

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AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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TOXIC HAZARDS RESEARCH UNIT
DESIGN AND CONSTRUCTION PHASE

J. D. MacEWEN

FOREWORD

This is the first of a series of annual reports concerning the Toxic Hazards Research Unit laboratory. This report describes the design and construction phase of a program directed by the Life Support Systems Division of Aerojet-General Corporation under Contract No. AF 33(657)-11305 for the Toxic Hazards Branch, Physiology Division, Biomedical Laboratory, Aerospace Medical Research Laboratories. The contract was initiated in support of Project No. 6302 "Toxic Hazards of Propellants and Materials" and Task No. 630201 "Toxicology". A. A. Thomas, MD, was contract monitor for the Aerospace Medical Research Laboratories.

J. D. MacEwen, PhD, is the principal investigator for the research program, while the design and construction phase of the program was directed by R. P. Geckler, PhD, F. P. Dillon, PE and B. D. Culver, MD.

Acknowledgment is made to R. G. Reichmann, J. A. Catuara, J. M. McNerney and E. H. Vernot for assistance in the preparation of this report.

This report is identified as Aerojet-General Corporation Report No. 3024.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
Biomedical Laboratory

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ABSTRACT

A facility was designed and constructed at Wright-Patterson Air Force Base for the specific purpose of conducting inhalation toxicology research. This facility is unique in that it has considerable functional variability and may be used for the study of space cabin toxicity under altitude and 100% oxygen conditions. Additionally, the laboratory was designed for use as a standard inhalation toxicology laboratory for the study of Air Force materials which may constitute a hazard to ground support personnel. This report describes the design and functional capability of the Toxic Hazards Research Unit laboratory which became operational in September of 1964. Toxicology research of the nature described has been initiated and will be reported upon as individual experiments are completed.

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SECTION I

INTRODUCTION

This is the first annual report of the Toxic Hazards Research Unit laboratory and is submitted in partial fulfillment of the requirements of contract AF33(657)-11305. At the request of the United States Air Force, this report was delayed until the facility design and construction phase of the contract was completed and covers the period 1 June 1963 through 15 February 1965.

SCOPE OF REPORT

The subject contract between the United States Air Force and Aerojet-General Corporation concerns the design, construction, equipping and operation of the Toxic Hazards Research Unit laboratory. This report will be primarily limited to a description of the design, construction and equipping phase of the laboratory.

A research program was initiated during the latter phases of the reporting period, a general review of which will be discussed in the summary of this report. Detailed toxicity reports will, however, be submitted as independent toxicity reports to the Air Force and will be consolidated in the annual reports.

TOXIC HAZARDS RESEARCH UNIT STAFF

The Toxic Hazards Research Unit (THRU) staff is composed of 30 direct labor personnel and three indirect labor personnel. The indirect labor staff is composed of two secretaries and a laboratory custodian. The staff was phased in throughout the facility design and construction period as equipment became available for research and manning reached its peak upon the completion of the Reduced Pressure Laboratory. The size of the staff was increased over the original contract agreement in accordance with a change of scope resulting from Air Force safety requirements established for the operation of the Reduced Pressure Laboratory. The Toxic Hazards Research Unit laboratory staff has, however, never been at full strength because of personnel turnover. Figure 1 is an organizational chart of the laboratory staff.

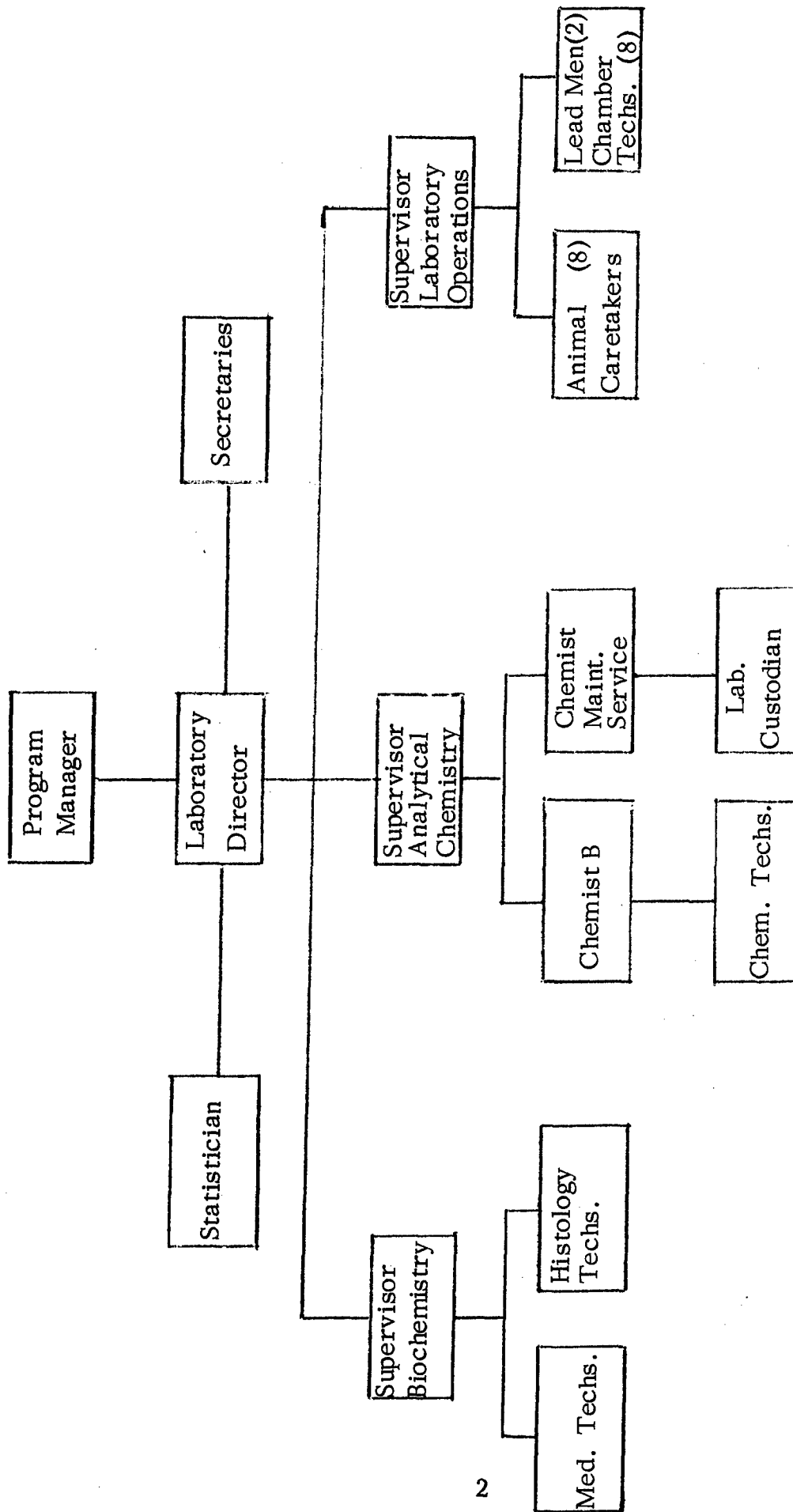


Figure 1. ORGANIZATION CHART - TOXIC HAZARD RESEARCH LAB

FACILITY DESIGN AND CONSTRUCTION

Facility design was initiated on 1 June 1963 at the Von Karman Center of Aerojet-General Corporation under the direction of the program manager at that time, Dr. Robert P. Geckler of the Life Support Systems Division, and Dr. J. D. MacEwen, the principal investigator of the Toxic Hazards Research Unit laboratory. The actual detailed design work on the facilities was the responsibility of the AETRON Division of Aerojet-General Corporation under the direction of Mr. Keith Folkerts. As design drawings were completed, they were submitted for review and approval to the Air Force Technical Contract Monitor, Dr. A. A. Thomas, Chief of the Toxic Hazards Branch of the 6570th AMRL, Wright-Patterson Air Force Base (WPAFB), Ohio.

The design phase consisted of three specific project areas: (1) the Ambient Pressure Laboratory, (2) the Reduced Pressure Laboratory, and (3) the Gas Dilution Facility. Each of these project areas will be described separately.

In the design of the facilities described in this report, one of the principal aspects of the design criteria was redundancy of critical components. This redundancy of selected laboratory components such as air blowers and vacuum pumps was required to insure continuity of research experiments. The redundancy would also reduce time loss in obtaining experimental data critical to Air Force planning.

SECTION II

AMBIENT PRESSURE LABORATORY EXPOSURE CHAMBERS

The Ambient Pressure Laboratory was built in one section of Building 79, Area B, Wright-Patterson Air Force Base, and required extensive revision of the existing facilities in this portion of the building. This laboratory was designed to serve as a standard inhalation toxicology laboratory similar to those used in the study of normal industrial toxicology problems. The laboratory contains four inhalation exposure chambers and three rectangular preconditioning chambers, each of which will be described in more detail in subsequent sections of this report. Two of the animal exposure chambers are standard Rochester-type chambers and two are of a new design, cubical in shape. The latter chambers were designed by Dr. Mars Y. Longley of the Life Support Systems Division of Aerojet-General Corporation.

The functional purpose of this laboratory is to conduct inhalation experiments on Air Force materials at normal atmospheric pressure. The tests to be conducted in this laboratory include: toxicity screening procedures, 4-hour LC₅₀ studies, emergency tolerance limit studies, 2-week and 6-week subacute studies, and chronic 6-month studies. The studies will not normally exceed 8 hours of exposure on any given day. The subacute and chronic inhalation exposures will consist of repetitive 6-hour daily exposures on a 5-day week basis.

This laboratory has been designed (see figure 2) to permit a single operator to control all four exposure chambers when operating under subacute or chronic exposure conditions. Additional personnel are required when acute toxicity testing programs are in process. The Ambient Pressure Laboratory is a ventilated and air-conditioned room which contains all the required accessory equipment such as chamber air-supply systems, exhaust systems, and exhaust air-cleaning devices. Two separate instrument panels have been provided, one for the control and monitoring of chamber supply air and one for the control and monitoring of contaminants introduced into the experimental chambers.

An equipment room at one corner of the Ambient Pressure Laboratory contains air-conditioning equipment, chilled water units and an air compressor for instrument control air.

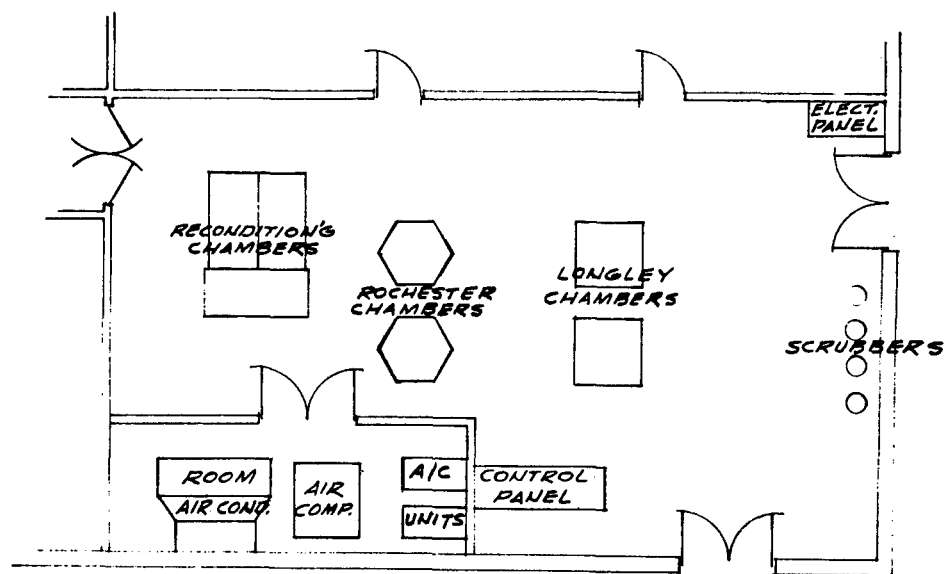


FIG. 2 AMBIENT LAB- FLOOR PLAN
 SCALE 1/4"=1'-0"

ROCHESTER CHAMBERS

Two standard Rochester inhalation exposure chambers were constructed and installed in the Ambient Pressure Laboratory. These chambers were fabricated to specifications provided by Professor Leonard Leach of the University of Rochester and are similar to chambers used in the Atomic Energy Research project at that university. Since a few modifications were made in the basic design provided by Professor Leach, a description of the chamber and the specific modifications will be provided.

The Rochester test chambers (figure 3) have a hexagonal-shaped central section approximately 4 feet across the flat sections and 3 1/2 feet in height. This central portion of the chamber (figure 4) is the animal exposure area and is divided into two levels. The lower level has a rigid, expanded metal floor and has a central expanded metal separation panel for segregation of animals by sex or species. The upper level is circular and is also constructed of expanded metal. This deck is mounted on rollers so that animal cages can be rotated from the back of the chamber to the front for removal.

Two doors, each representing one side of the hexagonal chamber, are located adjacent to the separating wall of the lower section. The entire chamber is constructed of stainless steel and Plexiglas. The upper and lower portions of the chamber represent truncated cones completely constructed of stainless steel. Hexagonal sections are made of Plexiglas panels mounted in stainless steel frames. The chamber air enters a small cylindrical section at the top of the truncated cone tangentially to increase mixing of the contaminant which has been added to the supply airstream. This design is to insure uniform contaminant concentration throughout the chamber.

The total chamber volume is approximately 1.5 m³ and can accommodate 8 beagle dogs, 4 monkeys, and 40 albino rats for periods of time up to 8 hours in duration. Although the chamber air supply is routinely regulated at 32 cfm, it may be varied from 5 to 50 cfm depending on the particular test requirements.

The specific variations made from the original Rochester chamber design are the method of exhaust air removal, the inclusion of an externally-operated water wash ring, and drainage system. These changes in the basic design were made to facilitate cleaning of the chambers after removal of the animals or to permit removal of animal wastes while the experimental animals remained within the chamber. An additional modification to the original chamber design was made on the access doors. As originally constructed, the access door frames were flexible and could not be made airtight.

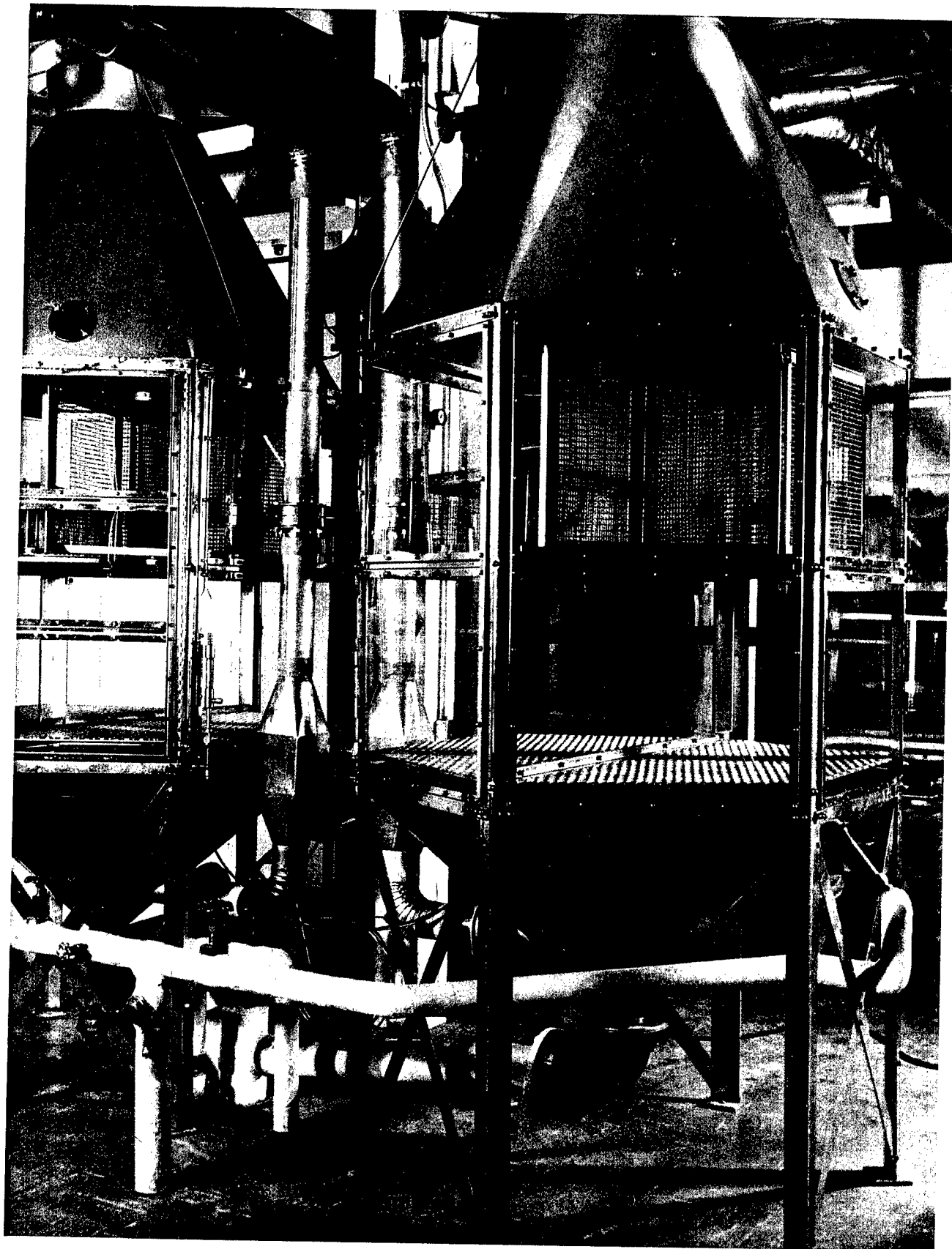
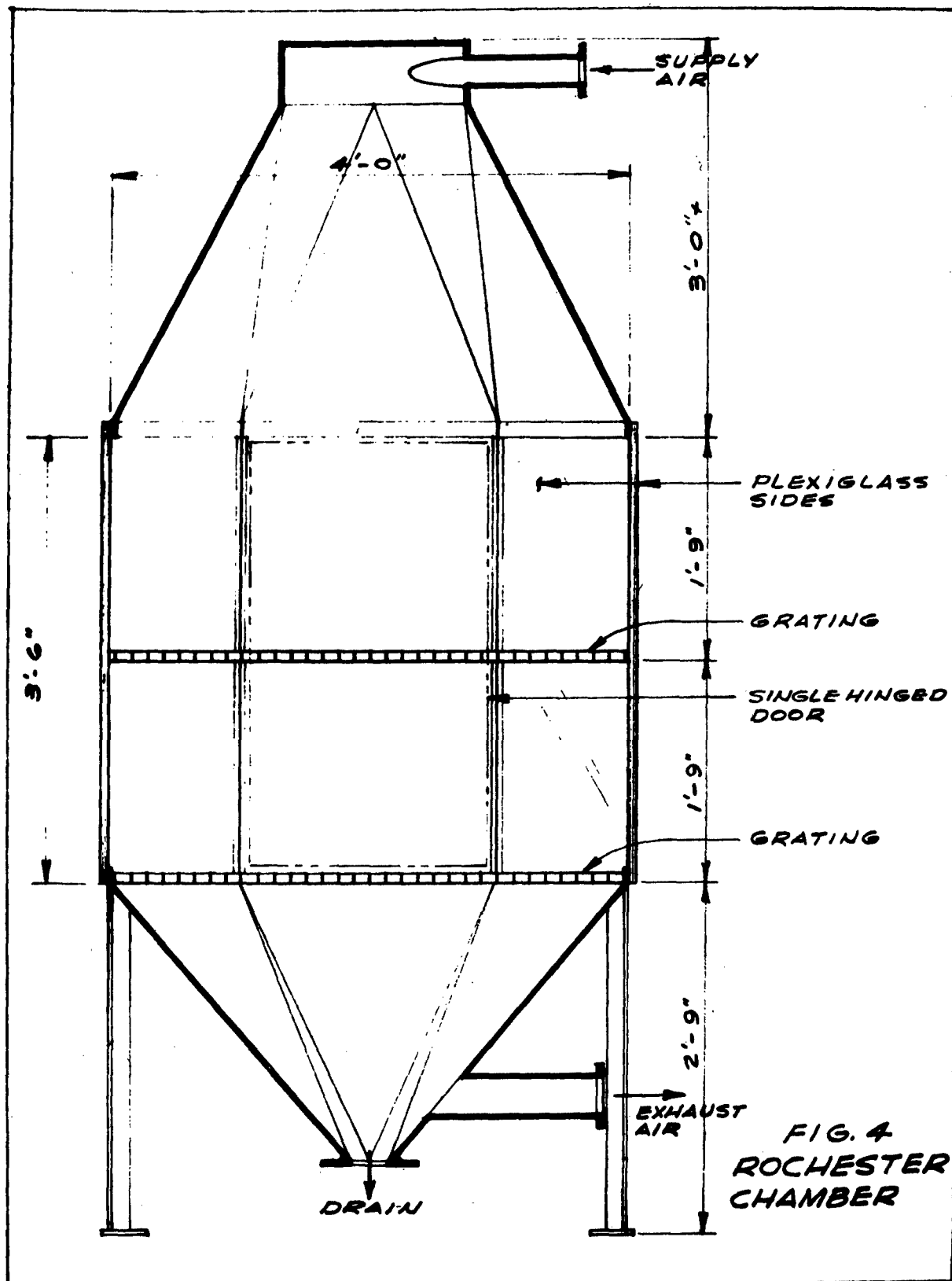


Figure 3. Rochester Exposure Chamber



(Cross Sectional View)

To make the doors as airtight as possible, a stainless steel, welded angle iron frame was mounted around the four edges of each door and rigidly bolted in place. This modification of the doors has resulted in an essentially leak proof chamber. The chamber is operated at a slight, negative pressure by adjustment of the air supply and exhaust fans. This system will prevent contamination of the general laboratory area.

LONGLEY CHAMBERS

The ambient laboratory has been equipped with two chambers which are more versatile in capability than the standard Rochester chambers. These Longley chambers, shown in figure 5, have a 4-foot cubical center section made of 3/8-inch thick, transparent Plexiglas with a stainless steel frame. The chamber has a truncated cone-shaped lower section (see figure 6) similar to the Rochester chamber in design. The upper section of the chamber is composed of four individual truncated cones which permit the chamber to be subdivided into units of two or four sections using either an independent air supply for each or a common supply for all.

When fully opened, the chamber is approximately 2.5 m³ in volume. The individual compartments are divided into a lower and upper level by means of a stainless steel, expanded metal grating.

The functional purpose of these chambers is to provide versatility in use as either a single large or several small individual chambers for acute toxicity work or for range-finding studies. When the chambers are subdivided into the four individual compartments, the same chamber may be used to house the control group of animals and animals exposed to three different concentrations of a given toxicant.

Individual air-sampling ports are located in each of the compartments so that samples for chemical analysis of the chamber air may be obtained. When the compartment dividers are removed and the chamber is fully opened, animal loading comparable to the Rochester chambers may be utilized. These chambers have also been provided with externally-operated washing and drainage systems.

PRECONDITIONING CHAMBERS

The preconditioning chambers, shown in figure 7, are utilized to condition test animals to the same temperature, humidity and air flow environment that is present in the Rochester and Longley test chambers.

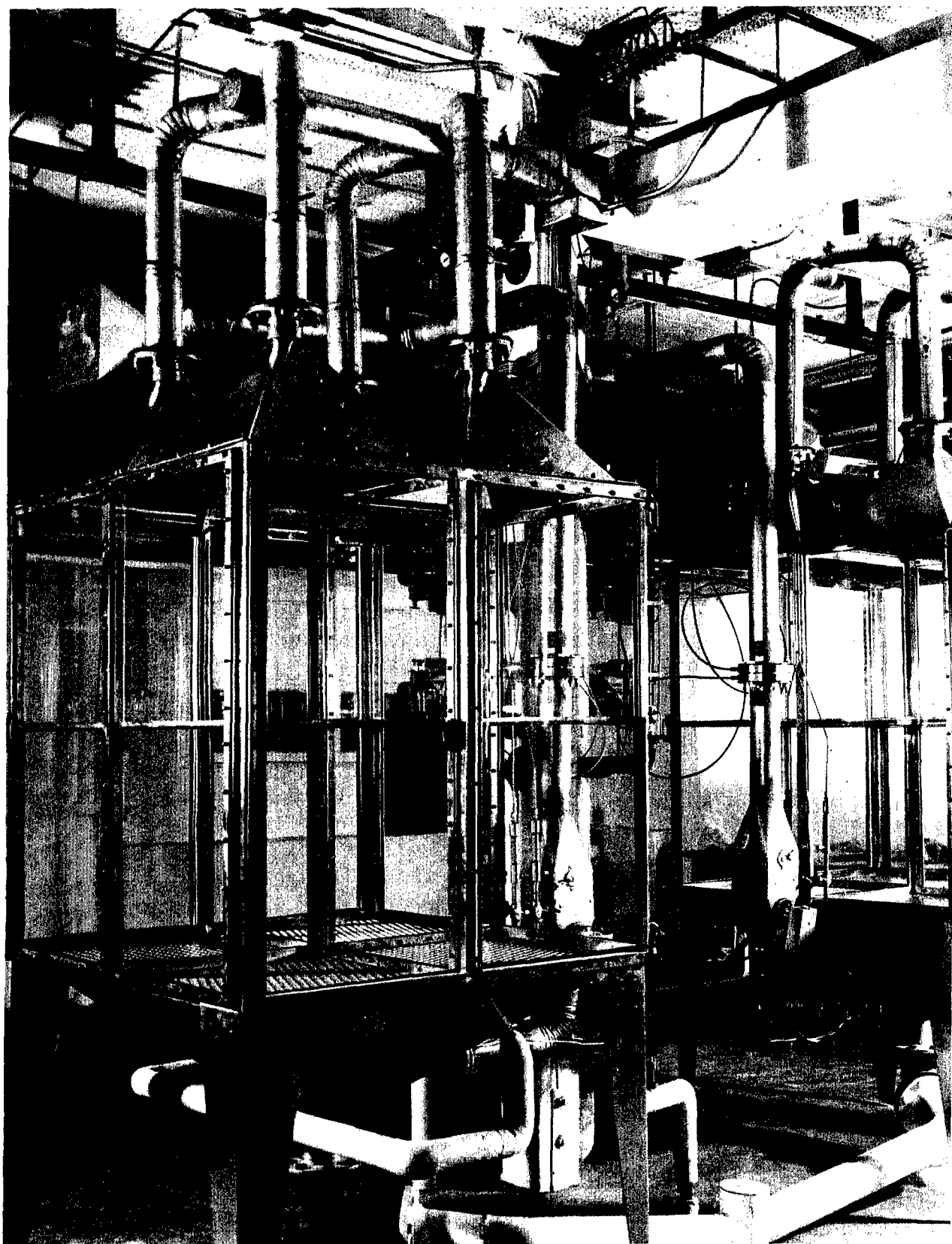
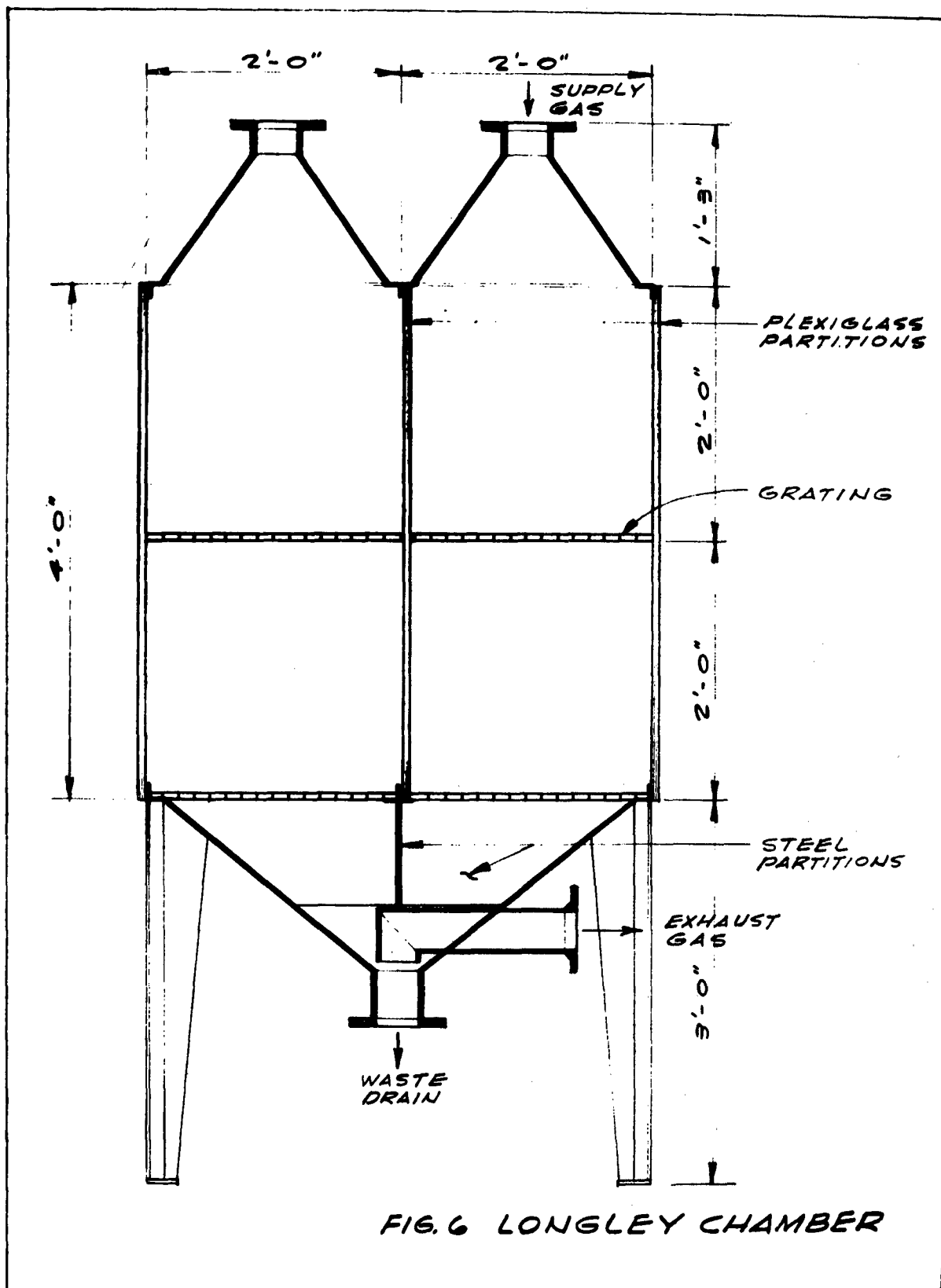


Figure 5. Longley Exposure Chamber



(Cross Sectional View)

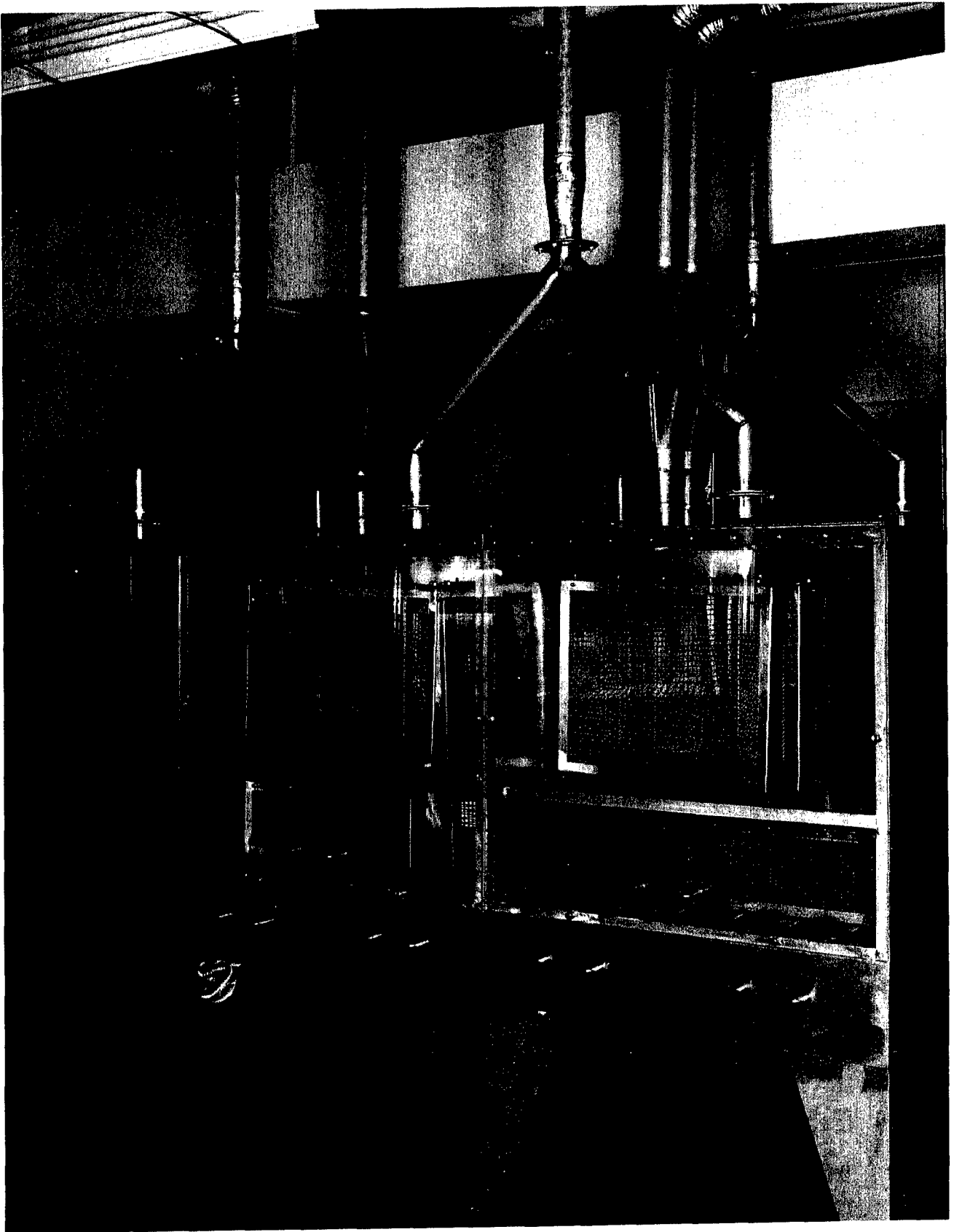
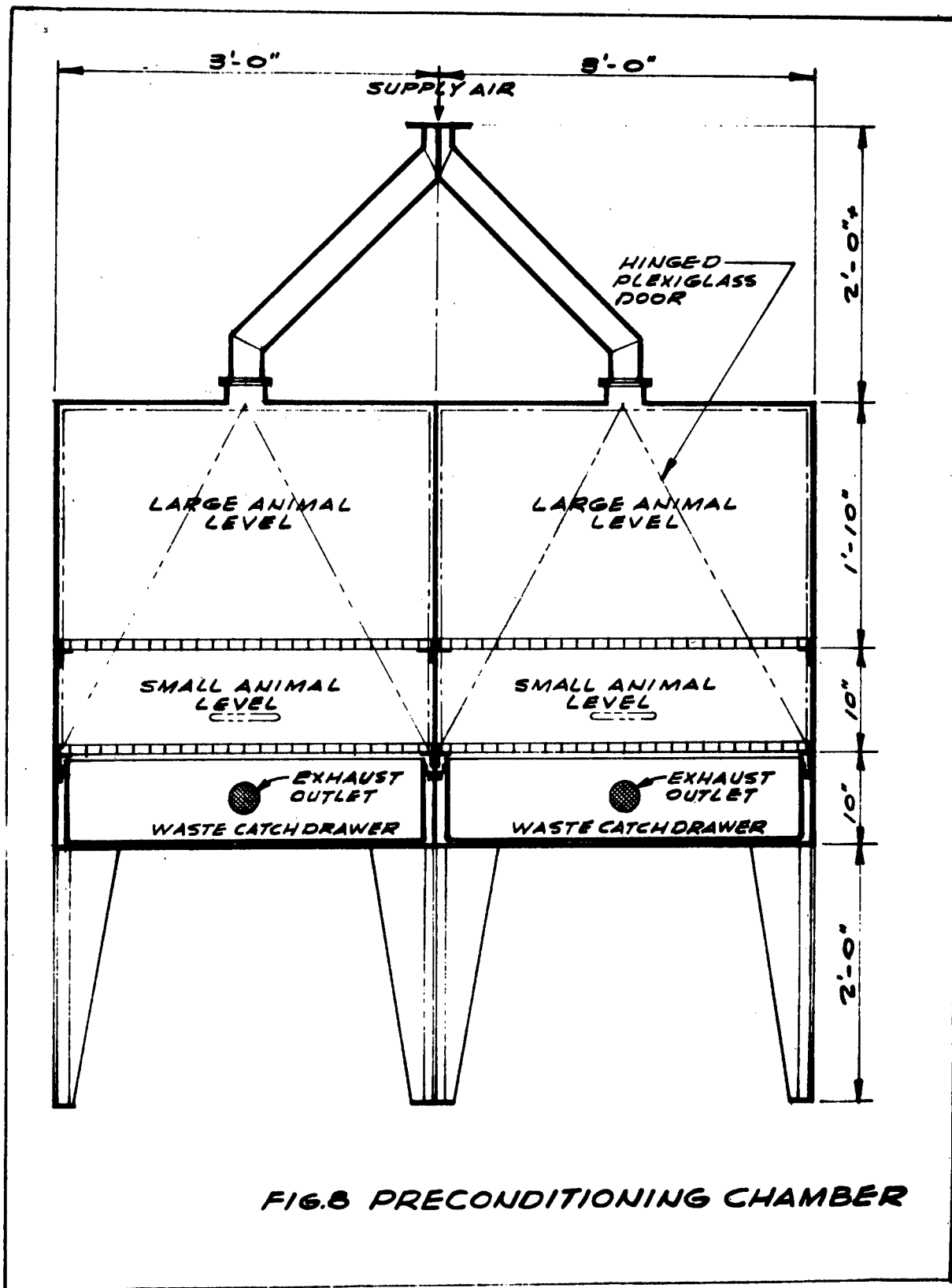


Figure 7. Preconditioning Chamber

No contaminants are present in the supply airstream to the preconditioning chambers at any time.

Each preconditioning chamber is a 72-inch wide by 32-inch deep by 42-inch high, rectangular, stainless steel enclosure, as shown in cross section in figure 8, with a transparent Plexiglas front for visual observation of the interior. The enclosure is separated into two equal compartments by a removable vertical metal partition. Each compartment is further divided into a 22-inch high upper level, a 10-inch high lower level, and an 8-inch deep removable drawer for retention and disposal of waste materials. The upper and lower level floors are made of stainless steel grating. Large or small animals are placed in the upper level while the lower level is utilized only for rats or other small animals. Rodents are never located under larger species for hygienic reasons.

Each of the two chamber compartments receives conditioned air through a 4-inch diameter diffuser located at the top. Air passes through all levels and exhausts through a 3-inch diameter, screened opening located at the back of the removable drawer. The front of each compartment is sealed with a transparent Plexiglas door, hinged at the top. The airflow to each preconditioning chamber is 24 cfm, 12 cfm to its sub-compartments.



(Cross Sectional View)

SECTION III

AMBIENT PRESSURE LABORATORY AIR SUPPLY AND CONDITIONING SYSTEMS

In accordance with the sound engineering and health practices described in the American Conference of Governmental Industrial Hygienists' manual entitled Industrial Ventilation, a work area in which toxic materials are stored or used should have a continuous supply of fresh air. Furthermore, no recycling of air should be permitted; therefore, the entire air supply for the heating and air conditioning of the ambient laboratory is composed of outside air. Figure 9 is a schematic diagram of the air-conditioning system designed to maintain the laboratory temperature at $72^{\circ} + 5^{\circ}\text{F}$. No attempt was made to control humidity at a specific level, however, the design was calculated to prevent the relative humidity from exceeding 55%.

The laboratory airflow of 1500 cfm is exhausted through a centrally-located ceiling relief vent. This vent also contains an emergency exhaust fan that can be operated from outside the laboratory in case of contaminant spillage or other emergencies. The following is a summary of the components and controls in the system shown in figure 9, starting from the fresh air intake and ending at the exhaust discharge point:

1. 1500 cfm of outside air enters the duct system and is preheated to 90°F by the preheat steam coil for the purpose of providing a minimum cooling load to the precooling coil. This pretreatment will prevent wear of the three-way chilled-water valve serving the precooling coil.
2. Air at 90°F is cooled to 70°F as it passes through the precooling chilled water coil.
3. The air is then passed through a flat filter box with replaceable Fiberglas filters and enters the air-handling unit.
4. The 70°F filtered air is next cooled to 53.5°F by the chilled-water cooling coil in the air-handling unit. This control temperature is necessary to remove sufficient moisture from the air so that relative humidity of the supply air can be maintained below 55% at maximum personnel occupancy.
5. The supply air is drawn through the air-handling-unit fan and discharged into the reheat steam coil. The Ambient Pressure Laboratory room thermostat controls the modulating steam valve serving the reheat coil

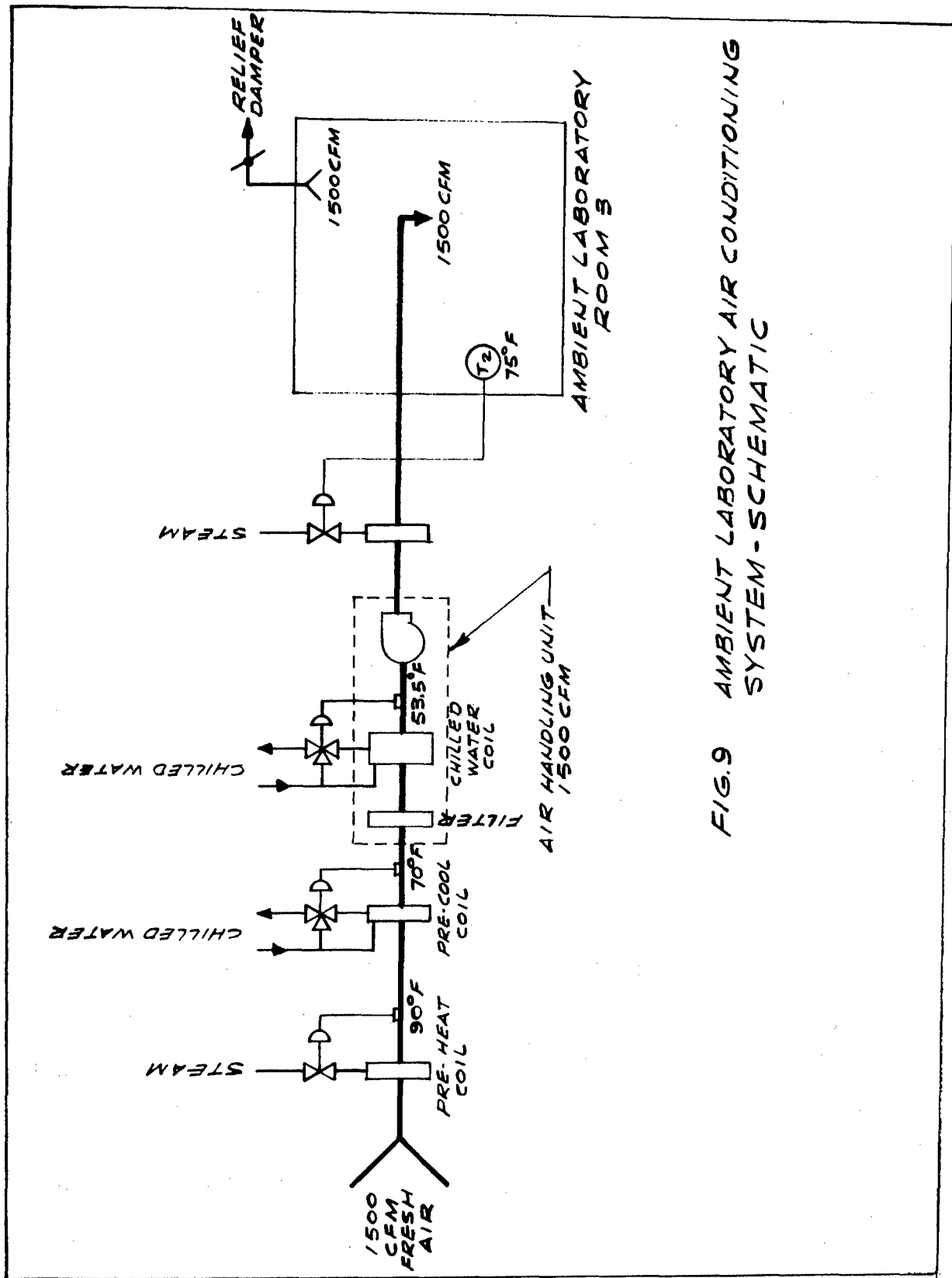


FIG.9 AMBIENT LABORATORY AIR CONDITIONING
SYSTEM - SCHEMATIC

so that the required heat is provided to maintain room conditions at $72^{\circ} + 5^{\circ}\text{F}$. The reheat coil can heat 1500 cfm from 55°F to 102°F if necessary. The fan brake-horsepower raises the air temperature from 53.5°F to 55°F .

AMBIENT PRESSURE CHAMBER AIR SUPPLY SYSTEM

The air-conditioning system to the test chambers is designed to provide clean air to which contaminants can be added in a metered quantity and to provide a constant environment for the animals being tested of $72^{\circ} + 5^{\circ}\text{F}$ and $50\% \pm 10\%$ RH. The air is made as clean as economically feasible.

Since the surrounding room is controlled at $72^{\circ} + 5^{\circ}\text{F}$, the only cooling load considered in the design of this system was the chamber animal loading. A diagram, figure 10, is shown of the air-conditioning system designed to maintain constant environmental conditions in the pre-conditioning and test chambers under variable animal loadings.

The following is a summary of the components and controls in the system shown in figure 7, starting from the fresh air intake and ending at the exhaust discharge point:

1. Air enters the system through an outside air intake and travels one of two alternate paths through a centrifugal fan and prefilters. Each pathway contains a fan and a set of filters, although one pathway constitutes standby emergency equipment.
2. 200 cfm of outside air is drawn through a Fiberglas disposable prefilter by its supply fan to remove large size particles of dust.
3. The supply air next passes through a fully open, manually-operated blast gate. A manually-operated blast gate on the discharge side of the standby supply fan is fully closed to prevent supply air from recycling through the inactive fan.
4. Air then passes through a 35% efficiency filter to remove smaller particles of dust and allows fairly clean air to enter the carbon filter which should have a clean surface to be most efficient. The carbon filter is utilized to remove objectionable gases which may distort test results. To be effective, this filter should be replaced at three-month intervals.
5. Air enters the electric preheat coil at ambient temperature and is heated to 70°F if below this temperature. The heat input is regulated by

a pneumatically-controlled variable transformer which in turn is controlled by a temperature-sensing element located downstream of the precool coil. This electric coil is capable of heating 200 cfm of outside air from minus 10°F to 70°F.

6. Air continues through the chilled-water precool coil and is cooled to 70°F if above this temperature. The cooling capacity of the precool coil is regulated by a three-way water valve which controls the amount of chilled water that enters or bypasses the coil. This valve is controlled by the same temperature-sensing element noted in paragraph 5. above. This coil is capable of cooling 200 cfm of outside air from 95°F to 70°F.

7. The supply air next enters a pan humidifier which operates to produce air saturated with water vapor at 70°F. The humidifier consists of a large water reservoir in which electric rod-type heaters continuously convert the water into steam vapor at a controlled rate. The water supply to the humidifier is pretreated by a commercial water softener.

8. The humidified supply air then enters the chilled-water recool coil in a saturated condition at 70°F and is cooled to 60°F. This treatment results in a relative humidity of 50% when the airstream is reheated to 72°F for introduction into the animal chambers.

9. The supply air passes through a manually-positioned valve which is set periodically by laboratory personnel to maintain a constant static pressure within the supply duct to the chambers. This air valve is required to compensate for variation in the ventilation system pressure drop due to the inline filters becoming loaded with dust particles. A high pressure drop alarm on the control panel will sound when the pressure drop across the filter series exceeds a preset value. The filter element in the 35% efficient filter frame should then be removed and replaced.

The estimated static pressure drop across the prefilter series is 0.2-inch H₂O when clean and 0.6-inch H₂O when dirty. Also this valve must compensate for the absolute filter located downstream, described in paragraph 10. below, which operates through a static pressure range of 1.0-inch H₂O to 2.0-inches H₂O.

10. The air continues through an absolute filter to remove 99.97% of all particles 0.3 micron in size and larger. A differential pressure indicator showing the pressure drop across the filter is provided.

11. The air supply is divided into two main ducts, one to the pre-conditioning chambers and the other to the test chambers. The air volume

to each duct may be varied so that any quantity from 0 to 150 cfm can be supplied to the three preconditioning chambers and 50 to 200 cfm can be supplied to the test chambers. The air is then distributed to each of the chambers through a series of branch ducts. The air quantity to each chamber can further be varied from 0 to 50 cfm. Presently, however, a balanced constant airflow is maintained to each chamber as follows:

a. Preconditioning chamber #1	24 cfm
b. Preconditioning chamber #2	24 cfm
c. Preconditioning chamber #3	24 cfm
d. Rochester chamber "A"	32 cfm
e. Rochester chamber "B"	32 cfm
f. Longley chamber "C"	32 cfm
g. Longley chamber "D"	32 cfm

12. The preconditioning chamber airstream passes through a single electric heater and is heated as required by a control signal from a sensing element in the combined exhaust duct from the three chambers so that an average of $72^{\circ}\text{F} + 5^{\circ}\text{F}$ is maintained in the chambers. Two manual air valves serving each chamber, one in the supply duct and one in the exhaust duct, can be utilized to either control the quantity of air serving the chamber or to isolate the chamber completely from the air-conditioning system. These duct valves can be positioned so that a negative pressure approximately 0.10-inch H_2O can be maintained in the chambers to prevent the escape of objectionable animal waste odors from the chambers into the laboratory. The air from all the preconditioning chambers is then exhausted through a common fan located outside of the laboratory.

The electric heating coil serving the preconditioning chambers is capable of heating 150 cfm from 60°F to 85°F which provides more than adequate capacity for maintaining the chamber air supply at 72°F .

13. The chamber air-supply system is divided into four branch ducts, each serving a single Rochester or Longley chamber. The following is a summary of a typical branch subsystem:

a. Air enters a manually-positioned air valve. This air valve is set so as to provide a balanced constant air supply to the exposure chamber. Slightly negative pressure can be maintained in the test chambers to prevent the escape of contaminant air into the laboratory environment by proper adjustment of the air supply and exhaust systems.

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b. Air then passes through an electric reheat coil and is heated, when required, to maintain $72^{\circ}\text{F} \pm 5^{\circ}\text{F}$ in the exhaust airstream from the individual exposure chamber.

c. Contaminants are metered into the airstream at this point and the mixture flows through the chamber animal-exposure compartment. Finally, the air flows into the exhaust duct and through another air damper system. The manual dampers in the supply duct and in the exhaust duct can be utilized to isolate a chamber from the remainder of the system.

d. The exhaust air is then passed through a disposable glass filter to remove large particles of contaminated dust and then through a carbon filter to remove objectionable gases which in some tests could contribute to general air pollution problems. These filters are easily replaceable and may be removed entirely if test conditions dictate.

e. Air continues to flow via one of two alternate paths through a centrifugal fan or its standby.

f. The exhaust air then passes through a fully open, manually-operated blast gate. A manually-operated blast gate on the discharge side of the standby exhaust fan is fully closed to prevent air from recycling through it.

g. The exhaust air may next be directed into either of two branch ducts by manually placing the two blast gates in opposite positions of fully open and fully closed. The air may either be directed through a water scrubber tower where some water-soluble toxic gases can be removed from the airstream. Alternately, the air may be diverted into a common exhaust duct leading from all four test chambers to an electrostatic precipitator where contaminant dusts can be removed before the exhaust air is discharged outdoors.

SECTION IV

AMBIENT PRESSURE LABORATORY MONITORING AND CONTROL SYSTEMS

CHAMBER ATMOSPHERIC ENVIRONMENT MONITORING AND CONTROL SYSTEM

A monitoring and control panel is located in the ambient laboratory in a position where the chamber operator can see all chambers and the panel simultaneously. This control panel, shown in figure 11, was designed to record continuously chamber environment and air-supply system variables. It is capable of providing visual and audible high and low alarm indication of malfunctions of the critical environmental parameters of the chamber air supply and internal environment.

The most critical parameter, temperature control, is automatically regulated by controller systems installed in the rear of the panel. These controller systems are operated by set points on the face of the individual strip chart recorders. Strip chart recorders have been provided for recording of temperature, airflow, and dew point of the air supply system to each of the individual chambers. The preconditioning chambers, however, are treated as a group and have a single sensing and recording system at their common air inlet and exhaust points.

Individual sensing devices are located at critical points within the chamber and the air-supply duct system which are monitored by a visual indicator located near the sensing points. These visual indicators are a part of pressure transmitter units which send an air signal to the instrument panel where that signal actuates individual strip chart recorders. While tests are in progress, continuous recordings are made of these parameters. Each of the individual strip chart recorders is connected to a pair of pressure switches actuated when critical preset high or low chamber conditions are achieved. Closure of the mercury-actuated pressure switch activates an alarm horn.

Temperature recorders connected by transmitters with the primary air-supply system operate through their controllers, either heaters or chilled-water coil valves, to maintain the supply air system at preset temperature levels. The temperature recorder-controller systems associated with individual exposure chambers actuate small duct-mounted heater coils if additional heating is required.

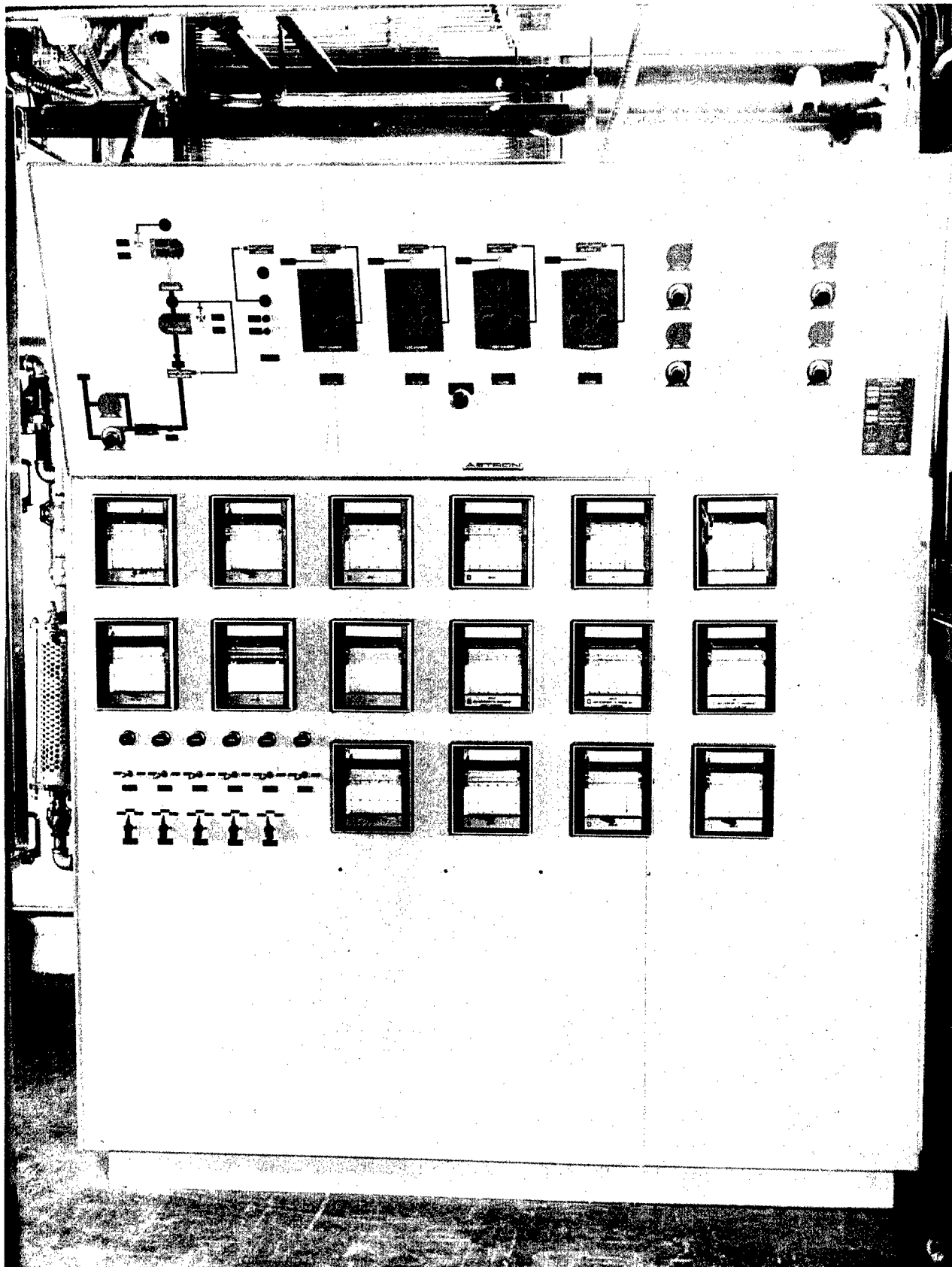


Figure 11. Ambient Pressure Exposure Chamber
Environmental Control Panel

The face of the upper portion of the monitor-control panel has a graphic display which consists of a flow diagram of the air supply and exhaust system from the outside air intake through the chambers, the exhaust blowers, air-cleaning systems and ultimately to the effluent discharge stack located on the roof of the ambient laboratory.

This graphic display section of the panel, shown in figure 12, has indicator lights, on the flow diagram, showing the location of each of the sensing devices included in the total system. Additional indicator points will be described in the ensuing discussion of the individual recorders. The following is a summary of the recording instruments on the lower section of the panel describing their function starting at the top and going from left to right through the three lines of recorders. However, it should be pointed out first that the two recorders in the upper left corner control and record the primary air-supply system. The two recorders immediately below these control the preconditioning animal chambers. The next four rows of recorders (appropriately marked on the graphic display) indicate from top to bottom air flow, dew point and temperature of the individual exposure chambers:

1. TRC-1 Temperature Recorder-Controller: 0°F - 100°F scale range records and controls temperature downstream of the preheater and precooler. This recorder controls the preheater when the temperature is 70°F or less and controls the precooler when the temperature is 75°F or higher. If the temperature rises above 80°F or drops below 65°F, respective alarm lights are actuated on the graphic display portion of the monitor panel. When the signal lights are actuated, the alarm horn system is also activated.

2. TRC-2 Temperature Recorder-Controller: 0°F - 100°F scale range records and controls temperature immediately downstream of the recool coil. The controller device is preset to maintain this temperature at 60°F. If the temperature drops below 55°F or rises above 65°F, respective alarm lights are actuated on the graphic display panel and an alarm horn sounds.

3. PR-1 Differential Pressure Recorder: 0-0.4" H₂O differential pressure scale range. This instrument records the airflow through Rochester chamber "A". The normal operating differential pressure is 0.3" H₂O vacuum when the chamber is operated at 32 cfm. This differential pressure is measured across a standard orifice-plate meter located in the exhaust duct of this chamber downstream from the flow-control valve. If the pressure drops below a preset limit or becomes positive, the respective alarm lights are activated on the graphic display panel and the alarm horn sounds.

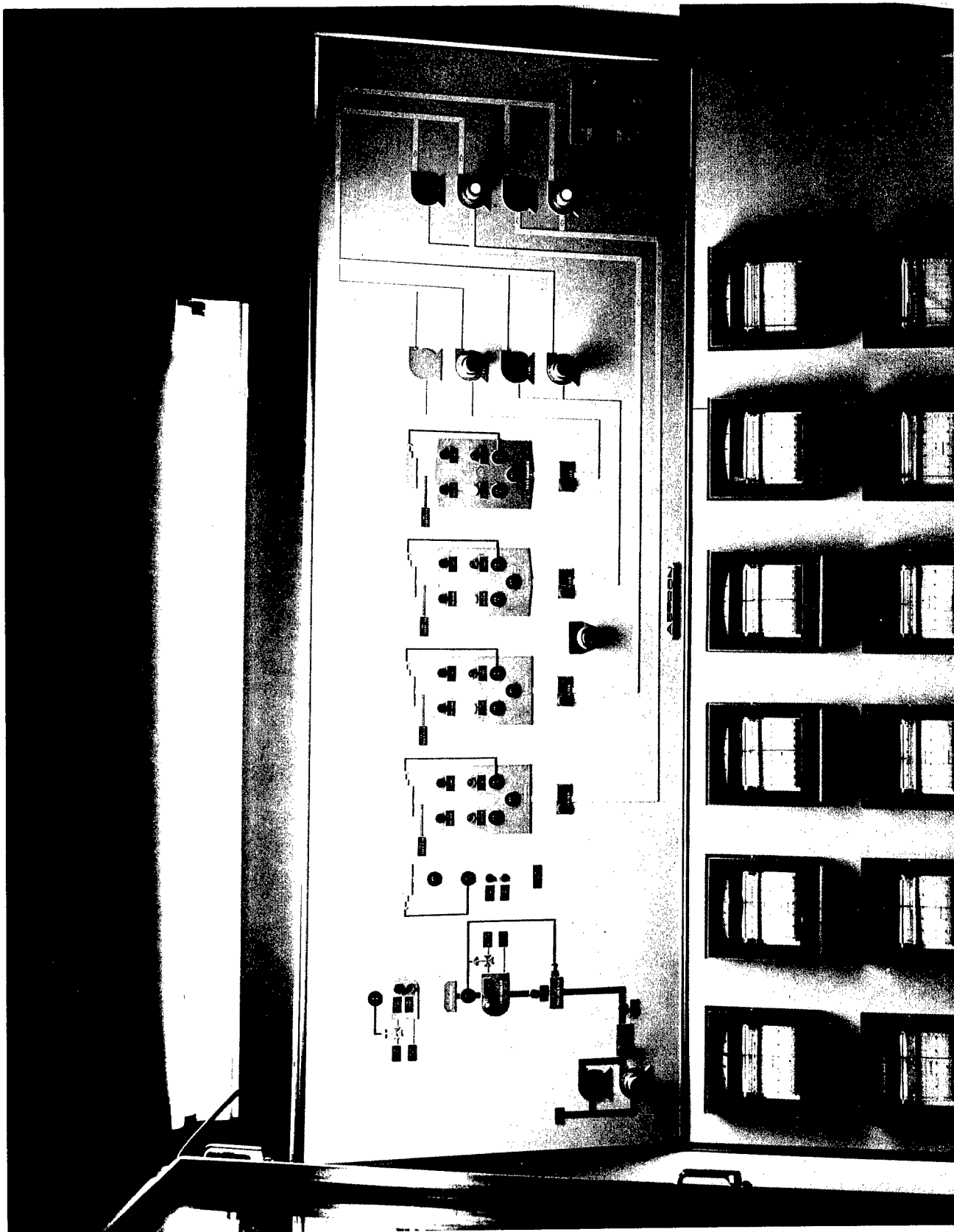


Figure 12. Graphic Display Section of Control Panel

4. PR-2 Differential Pressure Recorder: 0-0.4" H₂O differential pressure scale range. This instrument records the airflow through Rochester chamber "B".

5. PR-3 Differential Pressure Recorder: 0-0.4" H₂O differential pressure scale range. This instrument records the airflow through Longley chamber "C".

6. PR-4 Differential Pressure Recorder: 0-0.4" H₂O differential pressure scale range. This instrument records the airflow through Longley chamber "D".

7. TRC-103 Temperature Recorder-Controller: 0° - 100°F scale range. This instrument records and controls the temperature in the common exhaust duct from the three preconditioning chambers. Control is set to maintain 72°F. If the temperature drops below 68°F or rises above 80°F, the respective alarm lights are actuated on the graphic display panel and the operator is alerted.

8. MR-101 Moisture Recorder: The 0° - 100°F dew-point scale range of this recorder indicates the dew point of the exhaust air from all preconditioning chambers. Normal operating dew point is 55.0°F. Actual relative humidity values may be obtained from a psychrometric chart using temperature and dew point.

9. MR-1 Moisture Recorder: Indicates dew-point temperature of the exhaust air leaving Rochester chamber "A". The dew-point scale range is 0° - 100°F and the normal operating dew point is 55.0°F. As described above, this dew-point information may be used to obtain actual chamber relative humidity.

10. MR-2 Moisture Recorder: Indicates dew-point temperature of the exhaust air leaving Rochester chamber "B".

11. MR-3 Moisture Recorder: Indicates dew-point temperature of the exhaust air leaving Longley chamber "C".

12. MR-4 Moisture Recorder: Indicates dew-point temperature of the exhaust air leaving Longley chamber "D".

13. TRC-3 Temperature Recorder-Controller: 0° - 100°F full-scale range. This instrument records the temperature of the air leaving the Rochester inhalation exposure chamber "A". As previously described, the controller portion of this system actuates a variable voltage transformer

operating the duct-mounted individual chamber air reheater to maintain a constant chamber temperature of 72°F. If the temperature drops below 68°F or rises above 80°F, the alarm horn sounds and the appropriate signal light becomes illuminated on the graphic display panel.

14. TRC-4 Temperature Recorder-Controller: 0° - 100°F full-scale range. This instrument records the temperature of the air leaving the Rochester chamber "B".

15. TRC-5 Temperature Recorder-Controller: 0° - 100°F full-scale range. This instrument records the temperature of the air leaving the Longley chamber "C".

16. TRC-6 Temperature Recorder-Controller: 0° - 100°F full-scale range. This instrument records the temperature of the air leaving the Longley chamber "D".

Heater Switches

On the lower section of the face of the control panel, a series of toggle switches are located which control components in the chamber air-conditioning systems. These switches are arranged in the following order beginning from the extreme left:

1. Preheater
2. Reheat coil serving the Longley chamber "D"
3. Reheat coil serving the Longley chamber "C"
4. Reheat coil serving the Rochester chamber "B"
5. Reheat coil serving the Rochester chamber "A"
6. Reheat coil serving the Preconditioning chambers.

When any of the above toggle switches is placed in the "on" position, a pilot light above the switch is actuated.

Fan Switches

Immediately below the toggle switches described above, a series of three-way switches are located. Each switch controls a pair of fans located as follows from left to right on the panel:

1. Supply fan "a" or "b" serving the primary air supply system.
2. Exhaust fans "a" or "a-a" serving Longley chamber "D".
3. Exhaust fans "b" or "b-b" serving Longley chamber "C".
4. Exhaust fans "c" or "c-c" serving Rochester chamber "B".
5. Exhaust fans "d" or "d-d" serving Rochester chamber "A".

When either of the pair of fans common to a single chamber is switched to the "on" position, a red indicator light representing that chamber on the graphic display of the panel will be actuated by a pressure switch located in the exhaust duct system downstream of that set of fans. If this light is not actuated, a fan is not operating properly and should be checked.

In addition to those alarm lights previously described above, high and low alarm signal lights are located on the graphic display to indicate malfunction of the following subsystems:

1. High or low pressure differential across the 35% efficient fiber filter and the carbon filter located in series within the inlet air-supply duct.
2. High pressure differential across the disposable coarse filter and the carbon filter series located within the individual exhaust ducts leaving each of the Longley and Rochester test chambers.

An alarm silencing and indicator lamp test push button is located centrally on the graphic display. When an alarm is actuated, it continues to operate until this button is pushed by the laboratory technician on duty to indicate his acknowledgement that a problem has been noted. The flashing alarm light, however, continues until the laboratory technician has repaired or replaced the specific piece of equipment that is malfunctioning.

CONTAMINANT MONITORING AND CONTROL SYSTEM

A system was designed by the THRU staff to provide continuous monitoring and control of contaminant flow to the individual ambient pressure exposure chambers. This system provides a capability for automatic control of contaminant generation to a chamber only if the contaminant in use is capable of being monitored by automatic analytical instrumentation.

Contaminants are introduced into individual chambers through a pneumatic control valve, a needle valve, and either a panel-mounted glass flowmeter or a stainless steel, calibrated orifice-plate flowmeter from which they flow into the air-supply duct of the chamber. The pressure drop measured across the orifice-plate flowmeter is sensed by a differential pressure

transmitter which sends a signal proportional to the differential pressure input to a panel-mounted strip chart recorder. This recorder provides a permanent and continuous record of the contaminant flow to the chamber.

When a continuous monitoring analytical instrument is used for control of the contaminant generation rate, an electrical signal taken from the instrument output circuit is directed into a millivolt to pressure transducer and transmitter. This transmitter, having converted the electrical signal into a pneumatic signal, then directs its proportionally controlled output to a pneumatic strip chart recorder-controller unit. The recorder provides a continuous record of the actual chamber contaminant concentration and the controller, activated by deviations of contaminant concentration, sends a signal to the pneumatic control valve located in the contaminant feed line. Thus, as illustrated in figure 13, the pneumatic control valve modulates the contaminant feed to maintain the desired chamber concentration of the contaminant.

This system was primarily designed for use in chronic inhalation toxicity experiments where animals are exposed to the same contaminant concentration for daily 6-hour periods, five days per week, as long as six months in duration. Generally, high contaminant concentration, short-term experiments of the acute type do not lend themselves to continuous analytical monitoring and the subsequent use of the feedback system.

The recorders and recorder-controller device for contaminant-flow monitoring and contaminant-concentration monitoring and control are mounted as shown, figure 14, in a control console which was fabricated and assembled by the THRU laboratory staff. The console has four modular units, each containing the recorders and controllers for specific individual chambers. The modular units used for the Rochester chambers are equipped with one contaminant flow recording system and one contaminant chamber concentration recorder-controller device. The console modules associated with the Longley exposure chambers each have four individual contaminant flow metering devices but are equipped with a single contaminant-concentration monitoring recorder-controller system. These contaminant-concentration recorder-controller systems used in the Longley chambers are intended for operation when the chamber is modified for use in chronic inhalation toxicity experiments by removal of the compartmental partitions.

CONTAMINANT MONITORING (AMBIENT)

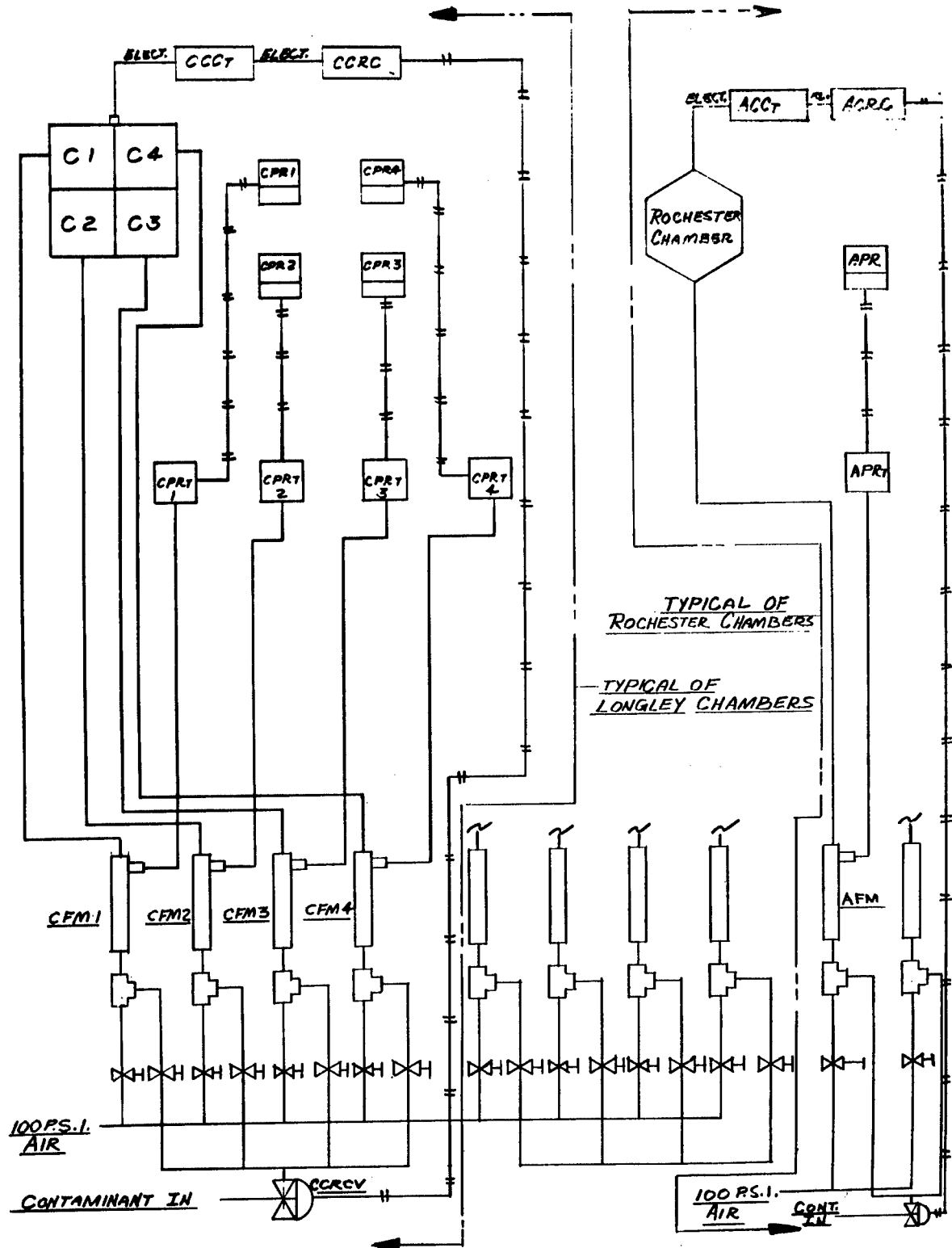


Figure 13. Contaminant Monitoring (Ambient)

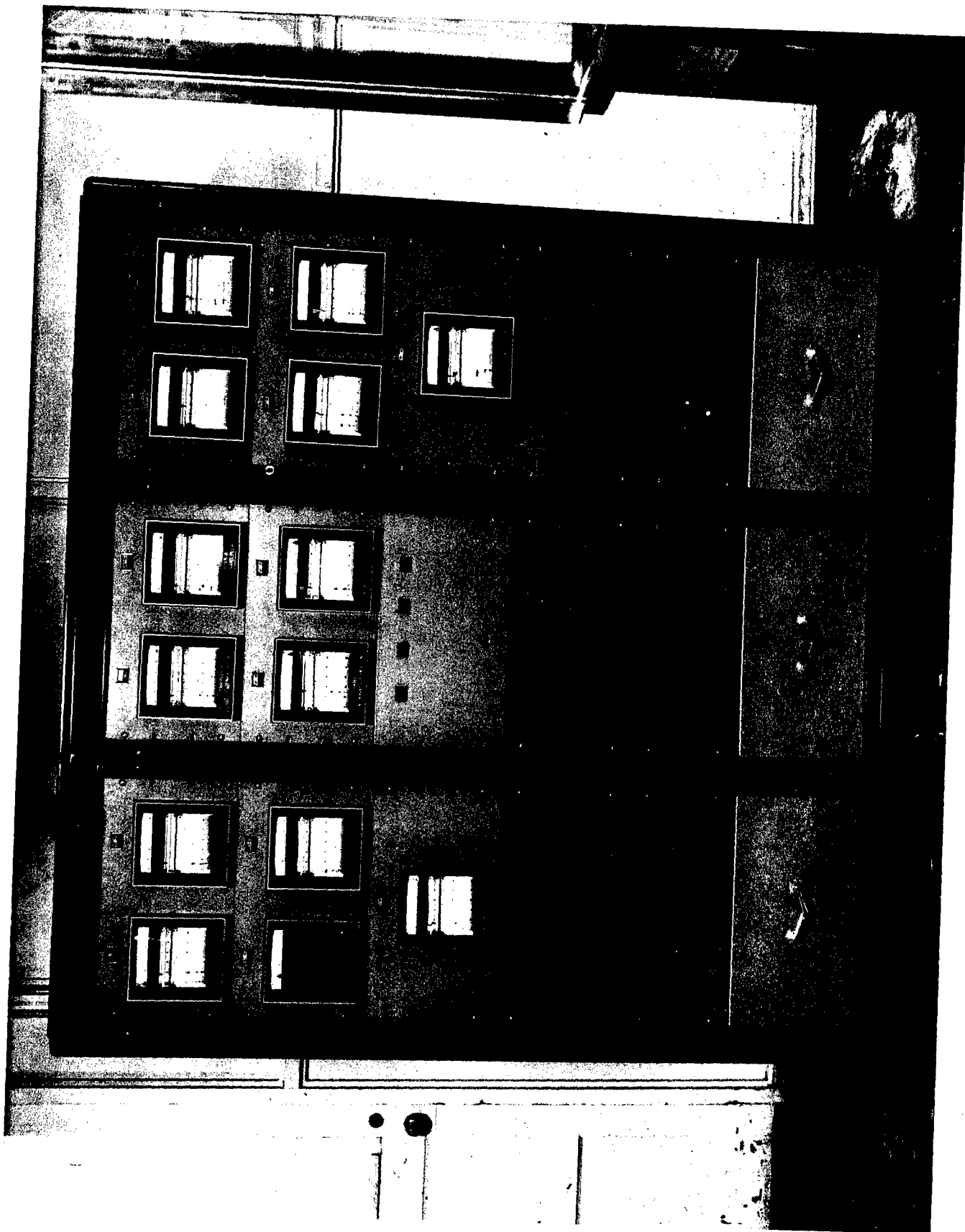


Figure 14. Ambient Pressure Exposure Chamber
Contaminant Monitoring Panel

SECTION V

CHAMBER EXHAUST AIR CLEANING SYSTEMS

AIR CLEANERS

When toxicity experiments are in operation, contaminants are added at a controlled rate to the air-supply duct of the individual exposure chambers. Contaminant which is not inhaled by the experimental animals or does not adhere to the chamber surfaces would normally continue to the outside discharge point where it could contribute to community air pollution. To prevent this, three types of contaminant removal devices are provided in individual chamber exhaust systems. Their description and purpose are as follows:

Duct Filters

The replaceable coarse filter and activated carbon filters located in the individual chamber exhaust ducts previously described.

Water Scrubber Towers

The water scrubber towers are cylinders 6-feet tall and 1 foot in diameter consisting of an inlet air distributor, a series of hollow ceramic rings, a water spray tube and a discharge air outlet. The airflow is counter current to the water flow. This unit will dissolve or absorb water-soluble contaminants. The ceramic rings are utilized to provide a large surface and a tortuous air path in order that maximum air-water contact can be accomplished. The contaminant containing waste water is then drained into the chemical sewage system.

Electrostatic Precipitator

The exposure chambers may be individually or jointly routed through the electrostatic precipitator which is a duct-mounted unit. This unit consists of removable plate cells, removable ionizers and a power pack. This precipitator model is rated at 90% efficiency and is utilized to remove the contaminant-laden dust particles or contaminant particles themselves.

Electrostatic precipitation is a method of removing dust and smoke from the air by electrical attraction. This is accomplished in this unit by

imposing an electrical charge of definite polarity on the dust particles through ionization and collection of the charged particles on Viscosine coated metal plates of opposite polarity. The plate cells may be removed and cleaned individually with hot water. The plate cells must then be re-coated with Viscosine for effective dust retention.

SECTION VI

INSTRUMENT AIR SYSTEM

INSTRUMENT AIR

The preceding description of the monitoring and control systems for environmental parameters within the chambers and the air-supply systems illustrates the use of pneumatic transducers, controllers and recorders. The most critical single piece of equipment for operation of the Ambient Pressure Laboratory, as well as the Reduced Pressure Laboratory to be described later, is the instrument air compressor. Interruption of the instrument air supply will result in the failure of all automatic controller systems. An oil-free air compressor system shown in schematic form, figure 15, was installed in the laboratory to provide high quality air to the sensitive control and recording instrumentation.

Since an uninterrupted supply of compressed air is essential to the continuous operation of the THRU laboratory, a standby government-furnished compressor was tied into the instrument air system as shown. This standby compressor is not of the oil-free type and is for use only under emergency conditions.

Alarms

An alarm has been provided in the event of air compressor failure. This alarm, a pressure switch, is mounted on the air receiver tank and activates the reduced pressure facility alarm horns when pressure drops below a preset level. The switch is connected in the normally closed position and, with loss of air, a relay is energized in the alarm circuit.

The pressure switch has been preset to indicate compressor failure at 60 psig in the receiver tank. This warning allows time for the chamber operator to switch over to the standby compressor before the air pressure drops to a critical level which would result in instrument failures.

The instrument air-supply system used for the transmission of pneumatic signals of various types has a color coding for ease of maintenance. The color coding used is as follows:

1. Red: 100 psig supply air to all primary systems
2. Orange: 3 to 15 psig signal air from transmitters to recorders

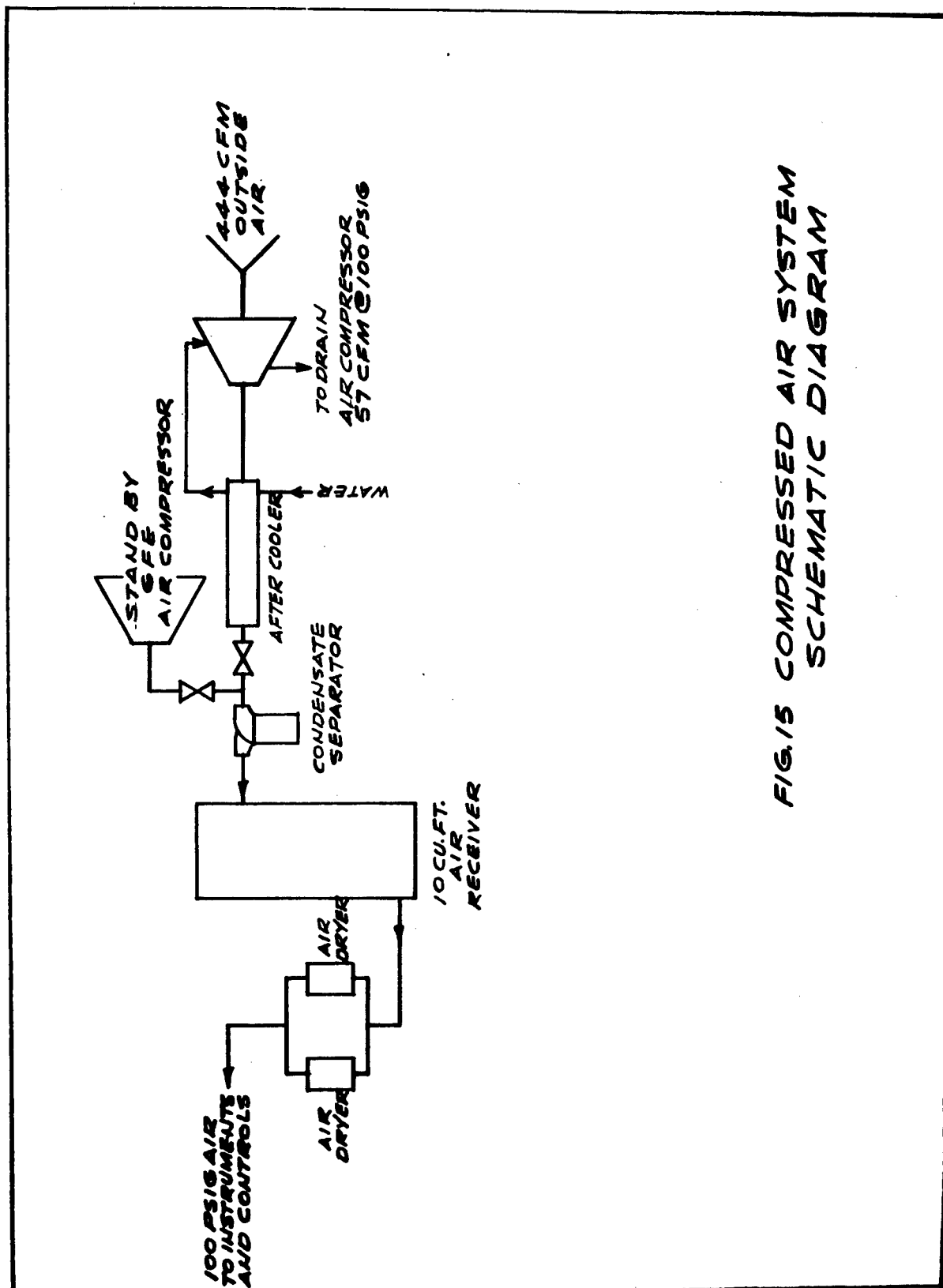


FIG. 15 COMPRESSED AIR SYSTEM
SCHEMATIC DIAGRAM

3. Yellow: 3 to 15 psig signal air to valves from controllers
4. Blue: 3 to 15 psig signal air from contaminant flow meters to recorders
5. Pink: 40 psig supply air to inflatable gaskets

SECTION VII

GAS DILUTION FACILITY

DESIGN

Building 79A is located approximately 600 feet from Building 79, Area B, WPAFB; therefore, it was considered satisfactory for the safe handling of highly toxic or unstable contaminants, after specific modifications were made to the structure and its ventilating system.

An area, 10-foot square, adjacent to the southwest corner of Building 79A was enclosed to house a fume hood. The original double doors in the south wall were removed and two hollow metal doors were installed on the west side of the new enclosure. The south side of the enclosure was an existing concrete wall which acted as a blast barrier. If a minor blast occurs within the fume hood, it is expected to be relieved through a corrugated plastic panel on the west side of the new enclosure. If a major blast occurs in this building, it will be relieved through the blowoff roof. The fume hood has its own supply and exhaust fans so that a minimum of room air is exhausted through the hood.

The entire building is heated and ventilated with a non-recycling air-handling unit located on the adjacent equipment room roof. This unit is provided with a duct-mounted steam coil which has a capacity to heat 1140 cfm of air from minus 5°F to plus 135°F. If a contaminant spill occurs in the building, a 1350 cfm emergency exhaust fan can be turned on at a panel located outside the building. A deluge safety shower and eye bath is located on the south wall of Building 79A for personnel who may accidentally come in contact with hazardous chemicals.

GAS DILUTION MANIFOLD

A gas dilution manifold system was designed to ensure maximum safety for the chemists and technicians conducting this operation.

The dilution of contaminants is made with dry, high purity, nitrogen fed from three separate manifolded banks of nitrogen cylinders. The pressurization of the blending cylinders containing the dilute contaminant-nitrogen mixture can be regulated and will be a function of the physical chemical properties of individual toxic agents. The usual gas mixtures prepared in this facility are 1% or 10% by volume, although a greater range of mixtures can be prepared if desired.

A liquid nitrogen cold trap was installed in the manifold system between the blending cylinders and the vacuum pump to protect the pump from corrosive gases and to prevent possible explosions. Upon completion of the cylinder-filling operation the cold trap is vented to the atmosphere. The small amounts of contaminant trapped do not constitute an air pollution problem during the venting procedure.

The sequence of a typical gas dilution operation, illustrated in figure 16, is as follows:

All Valves Closed - Start of Cycle

First Operation - Clean Out Lines

1. Open Main Line Flow Valves F1 & F2
2. Open All Blending Cyl. Valves B1, B2, B3 & B4
3. Open Cold Trap Valve T
4. Open Vent Valve V
5. Open (Crack) Nitrogen Valve N1, N2 or N3
(Just enough to blow out system)

Second Operation - Vacuum Build-Up in Blending Cyls.

1. Close the Opened Nitrogen Valve
2. Close Flow Valve F1
3. Open Vacuum-gauge Valve G2
4. Close Vent Valve V
5. Open Vacuum-pump Valve P
6. Start Pump

Third Operation - Draw Off Contaminants (2 Cyls)

1. Close Cold Trap Valve T
2. Stop Pump
3. Close Pump Valve P
4. Open Flow Valve F1
5. Open Desired Contaminant Valve C1 or C2

NOTE: If Contaminant Cylinder is Pressurized, Close Vacuum Gauge Valve G2 and Open Pressure Gauge Valve G1.

Third Operation - (Alternate) - Contaminant From 1 Liter Cyl.

1. Close Cold Trap Valve T
2. Stop Pump
3. Close Pump Valve P
4. Open Contaminant Valve C4

NOTE: If Contaminant Cylinder is Pressurized, Close Vacuum Gauge G2 and Open Pressure Gauge Valve G1.

Fourth Operation - Pressure Blending With Nitrogen

1. Close Contaminant Valves (C1, C2 or C4)

2. Close Vacuum Gauge Valve G2
3. Open Pressure Gauge Valve G1
4. Check for Open Both Flow Valves F1 & F2
5. Open Nitrogen Valve N1, N2 or N3

Fifth Operation - Completion of Blend

1. Close Nitrogen Valve N1, N2 or N3
2. Close Blending Valves B1, B2, B3 or B4
3. Detach Blending Cylinders
4. Check for Closed Contaminant Valves C1, C2, C3, C4
5. Detach All Contaminant Cylinders
6. Open Cold Trap Valve T
7. Open Vent Valve V
8. Check for Open Flow Valves F1 & F2
9. Close Gauge Valve G1
10. Check for Closed Gauge Valve G2
11. Open Nitrogen Valve N1, N2 or N3 briefly to blow out the lines
12. FINAL - Close All Valves Before New Cycle

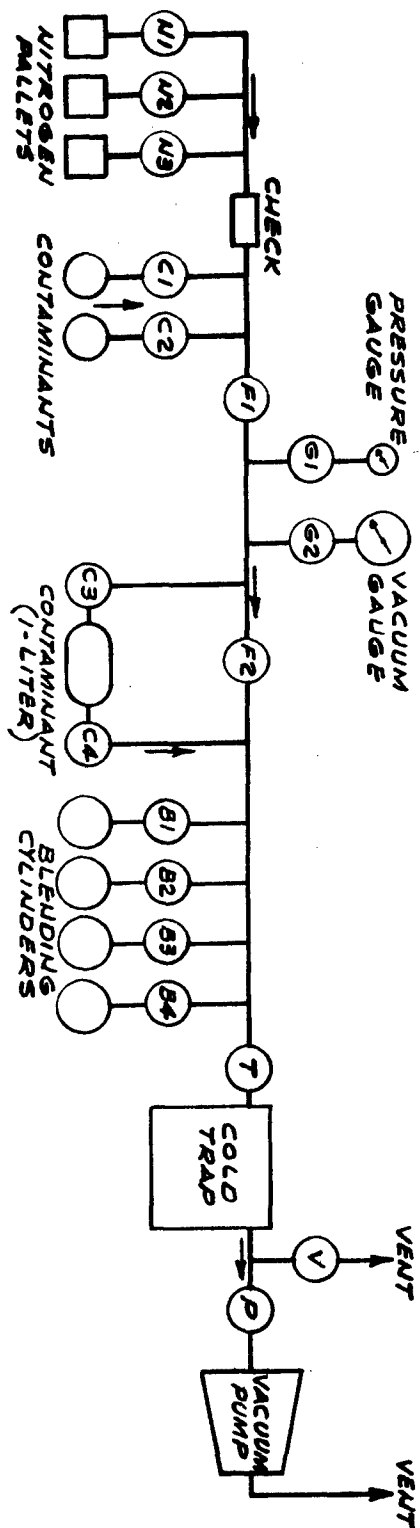


FIG.16 GAS DILUTION MANIFOLD SYSTEM

SECTION VIII

REDUCED PRESSURE LABORATORY

FUNCTIONAL PURPOSE

The Reduced Pressure Laboratory, also referred to in this report as the altitude laboratory, was constructed in a one-story addition with full basement, located on the southwest corner of Building 79, Area B, WPAFB.

The functional purpose of this laboratory is to provide continuous exposure of experimental animals or humans to trace contaminants found to be present in space capsules in specially designed dome-shaped chambers capable of operating at 5 psia with a 100% oxygen environment. Four such domes, which were conceptually designed by Dr. A. A. Thomas, Chief of the Toxic Hazards Branch, 6570th AMRL, and commonly referred to as the Thomas Domes, are located on the first floor of the building addition. Also located on the main floor is the master control panel for continuous monitoring and operation of this facility.

The basement to the building addition contains the four airlocks attached to each of the domes and through which dome entry must be made to prevent interruption of continuous exposure experiments. Also located in the basement are both room and dome air-conditioning systems, the contaminant generation systems, dome air-and oxygen-supply systems, and dome pressure regulation equipment.

In a corner of the basement, an equipment room contains three high volume vacuum pumps for operation of the domes at reduced pressure. Two pumps are capable of operating the domes at full design capacity while one serves as an emergency standby to prevent interruption or abortion of experimental programs. In an adjacent area of the basement, a walled enclosure serves as a clothing change room for laboratory technicians where street clothing is exchanged for special fire retardant coveralls for dome entry. This room also houses the self-contained boiler system for generation of steam used in the control of relative humidity within the domes.

The unique functional capability of the laboratory should not be overlooked. The four domes are capable of completely independent operation. These chambers are capable of the following conditions:

1. Pressure control variable between 5 psia and ambient
2. Atmospheric composition compatible with an essentially pure oxygen atmosphere (96% or better)

- either gas
3. Oxygen or oxygen-air flow mixtures from 0 to 100% of
 4. Gas flow rates between 18 and 100 cfm
 5. Temperature control within the domes at $72^{\circ} + 5^{\circ}\text{F}$
 6. Relative humidity control within the domes at $50 \pm 10\%$ RH
 7. Continuous, indefinitely long exposure capability

All of the above specifications have been met under the most severe test conditions - specifically, temperature and humidity control with minimum and maximum gas flow rates. Oxygen purity within the chambers was tested at minimum flow conditions in order that maximum dilution due to leaks would be apparent. The continuous reduced-pressure exposure unit was tested for independent operation of the individual chambers according to the following schedule and found satisfactory:

<u>Chamber No.</u>	<u>Absolute Pressure</u>	<u>Gas Supply</u>	<u>Gas Flow Rate</u>
1	250 mm Hg	O ₂	18 cfm
2	250 mm Hg	O ₂	100 cfm
3	380 mm Hg	40% O ₂ -60% air	18 cfm
4	760 mm Hg	Air	18 cfm

This facility was designed to enable the laboratory to evaluate potential toxic hazards in closed environments and to establish tolerance limits for human exposure during long-term space flights under controlled conditions of temperature, relative humidity, pressure and variable gas mixtures.

DOMES DESIGN AND CONSTRUCTION

The removable dome and permanent floor section of the Thomas Domes are shown in figure 17. The dome, shown in cross section in figure 18, is constructed of high tensile strength steel plate, and tempered polished plate glass. A 4-foot high sloping area consists of twenty flat glass panels which are held in place with spring clips. The 1-inch thick windows, each approximately 2-foot wide are gasketed with 1/4-inch neoprene to prevent leakage and they are separated by vertical steel members that rise to a common steel ring. Above the window section is a steel bumped head which has two vertical stiffener ribs across the top of the dome. At the center of the dome top a lug and yoke have been positioned for lifting by the overhead bridge crane.

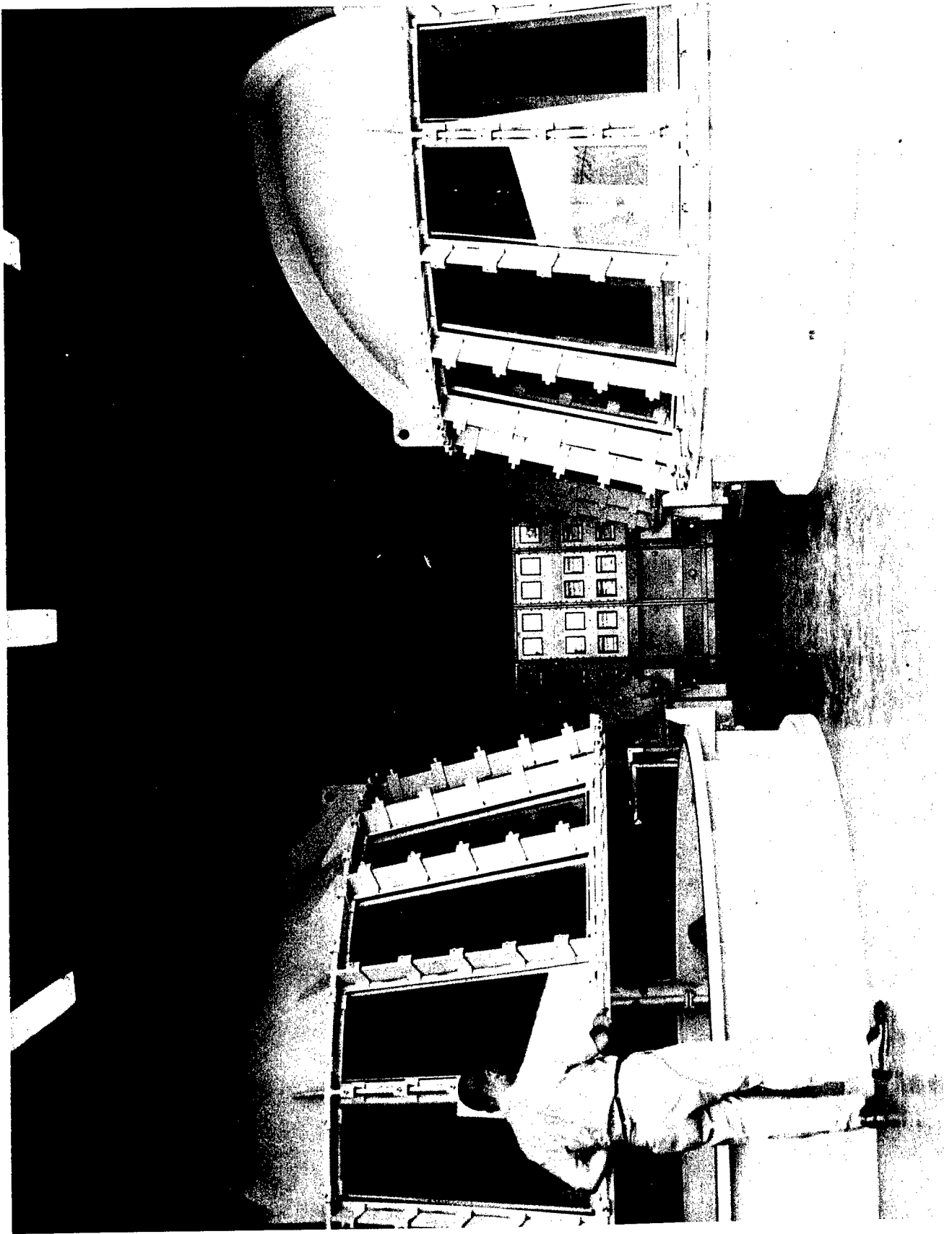


Figure 17. Thomas Domes

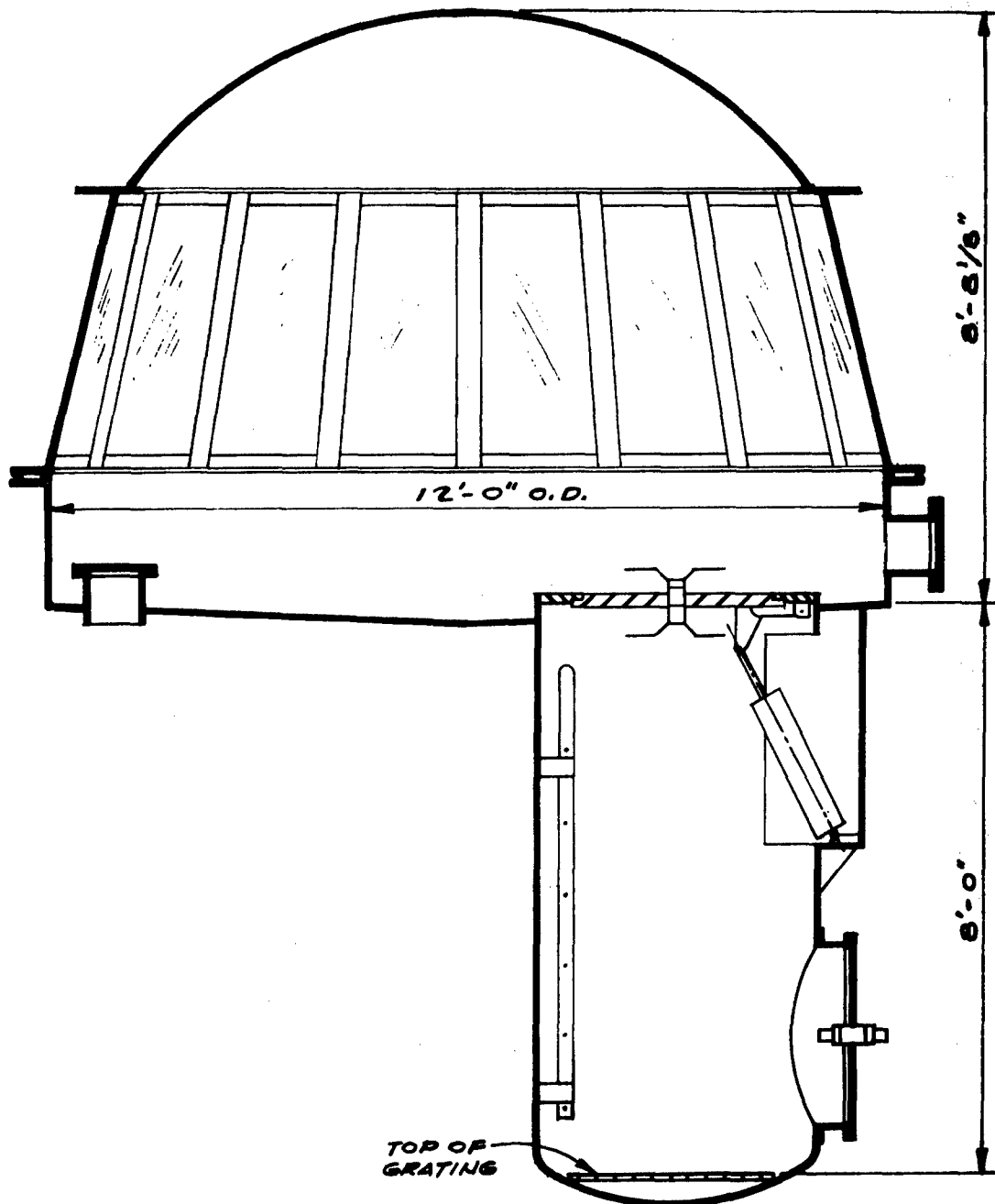


FIG.18 THOMAS DOME

(Cross Sectional View)

The floor section consists of a steel bottom with the airlock projecting slightly above the floor level to prevent liquids from draining into the airlock. A vacuum waste drain is located in the same dome quadrant as the airlock. A 21-inch high steel vertical section is flanged to connect with the upper dome section.

The design parameters utilized for construction were as follows:

1. A pressure differential between the inside and outside of the domes of 10 psi
2. A fourfold safety factor for steel members based on ultimate tensile strength
3. A tenfold safety factor for tempered glass plate based on ultimate tensile strength

To further safeguard the dome against collapse, a pressure relief valve, preset to open if the pressure dropped below 230 mm Hg absolute, is located in the dome head.

Service penetrations to the dome section are made through two circular bolted plates, hereafter referred to as penetration plates. All lines, wires and ducts passing through these plates have been designed so that the plates may be removed for future additional penetrations of required utility services.

One penetration plate is located in the floor near the lock hatch. The plate includes the supply and return air ducts, safety shower and hose water line, and an electric conduit for the interior light. The other penetration plate is located on the side of the dome just above the floor and includes penetrations for shielded electrical conductors to be utilized for transmission of instrumentation signals. Dive valves, manually operable from inside or outside of the dome, are located near the edge of the bumped head that forms the top of the dome. In an emergency, the dive valves may be opened, allowing the dome to return to atmospheric pressure rapidly. The top section of the dome can then be lifted approximately 8 feet so that aid can be administered to personnel inside the dome.

The permanent base section of the dome and the removable dome head are gasketed with an inflatable o-ring gasket specially designed for this purpose. The o-ring is inflated to 40 psig to prevent any leakage at this juncture during reduced pressure operations. The air pressure required for inflation of the o-ring is obtained from the main laboratory instrument air system.

Two major modifications in the operation of the inflatable o-ring gasket were made by the THRU laboratory staff. The first modification was made to prevent overinflation and rupture of this gasket when the top section of the dome is raised for routine cleaning, animal loading or in the event of an emergency opening of the dome. A lever-actuated microswitch, normally open, closes a three-way solenoid valve in the air-supply line to the o-ring gasket when the dome top is raised more than a half inch above the base section. At the same time that the air supply is interrupted, the o-rings are vented to atmosphere and deflated.

The second modification of the o-ring gasket was the provision of an automatic switching device from laboratory instrument air to bottled compressed air in the event of air compressor failure. This allows the domes to remain isolated during power failures until such power can be restored, preventing unnecessary loss of expensive research experiments.

Instrument air, supplied through a regulator which reduces the pressure to 40 psig, operates a three-way pneumatic valve which is normally closed. In instrument air failure, the diaphragm-operated three-way valve switches the air-supply line of the dome o-rings to the other port, which, in turn, is connected to compressed air cylinders providing 40 psig air through pressure-reducing valves.

As the construction phase of the reduced pressure facility neared completion, some additional equipment was installed for exposure of experimental animals. The first of these was the fabrication and the installation of animal holding cages. Rat cages of standard design were modified for suspension from the flange section of the dome head so that the rats housed in these cages could be observed by the chamber operator. Standard monkey cages, similar to those used in the ambient chambers, were modified for use in the domes and were fitted into specially constructed frames made of angle iron which were situated in one quadrant of the dome floor.

One half of the dome space was utilized for the construction of dog pens. These dog pens were constructed with an expanded metal floor mounted approximately 6 inches above the dome floor so that animal waste could be removed with maximum efficiency. The walls of the dog pens were constructed of standard kennel fencing sections, including gates, and 2-inch by 4-inch standard fencing material was used to provide tops for these pens. The pens are divided into two sections for segregation of dogs by sex.

All installations within the dome were made to provide clean, comfortable housing for the experimental animals and to allow maximum hygienic standards to be maintained. This would allow research programs to be conducted with minimum interference to the desired experimental parameters.

A water-flushing ring was installed around the perimeter of the base section of each dome for periodic flushing and draining of animal wastes and food residues to prevent a buildup of odor and atmospheric contamination. An additional penetration was made in the side dome penetration plate, and a water line was connected to the annular flush ring. The control valve is mounted on the outside of the dome so that this flushing can be effected at 4-hour intervals by the chamber operator during continuous exposure periods.

Another penetration was added to provide a watering system which could be manually controlled by the chamber operator for providing drinking water to dogs housed within the dome. Chamber operators making routine inspections of the animals within the dome are instructed to fill the water bowls of these animals by the external valve when required.

Since standard laboratory watering devices such as inverted bottles with drinking tubes could not be used under reduced pressure conditions, an automatic watering system was designed and installed. This system was connected to the water line already in existence within the dome for purposes of daily cleaning. A pressure reducer and gauge were connected to the water-supply line and 1/4-inch copper line was taken off from this point through a tee, one line serving the battery of monkey cages and the second line serving the rat cages previously described. The section of water line leading to the rat cages was provided with an automatic disconnect so that the line would not be damaged in routine or emergency lifting of the dome. In each individual rat or monkey cage, a stainless steel automatic watering device was installed. These devices require depression of the valve nipple by the tongue of the animal for water flow to be initiated.

WASTE DISPOSAL SYSTEM

A waste drain line was installed near the center of the bottom section of each dome. The drain line is immediately followed below the dome by a manual shutoff valve to prevent back suction of sewage when the domes are operating at reduced pressure conditions. The waste lines from all four domes lead into a vacuum waste tank of 100-gallon capacity. This waste tank is evacuated by a standard laboratory vacuum pump to a pressure slightly more negative than the dome to insure flow from the dome to the tank. The waste tank is drained into the base sanitary sewer system after isolation from the dome and atmospheric venting. A flush water system with vacuum breaker has been installed on the upper portion of the waste tank for periodic flushing to prevent accumulation of residual animal wastes including unused food washed through the system.

To prevent overfilling of the waste tank and backflow into the vent system, a mercoid differential pressure switch was installed on the tank. When the waste tank is filled to a preset level, a red warning light flashes both at the waste tank and above the control console in the dome area. When the warning light appears, cleaning operations are temporarily suspended for emptying of the tank by one of the chamber operators on duty.

AIRLOCKS

The airlock section of the Thomas Dome, shown in figure 19, is depressurized by dome entrants, using a procedure detailed in the section of this report entitled Standard Operating Procedures. It may also be used for addition or removal of test animals from the dome without interruption of continuous exposure studies.

The airlock depressurization and repressurization operations are controlled by the dome entrants using valves located within the airlock. A solenoid valve located in the lock evacuation line is controlled by one of two safety observers on duty during all dome entries. Therefore, it takes a minimum of two chamber technicians to effect dome entry. This feature was added to eliminate the possibility of suicide attempts.

The airlock is a cylinder 4-feet in diameter by 8-feet in height which includes the following features:

1. A 30-inch diameter access port with the door opening outward
2. A 30-inch diameter counterbalanced hatch for access from the lock to the dome and opening downward into the lock
3. An aluminum ladder to facilitate climbing in and out of the dome
4. An 8-inch diameter window located to provide convenient and continuous surveillance of the airlock occupant by the chamber technician on duty outside the lock
5. A pressure gauge indicating the airlock pressure is located on the outside of the lock.
6. An altimeter is mounted inside the airlock to assist the dome entrant in controlling the rate of depressurization and repressurization.
7. A system of oxygen flushing, depressurizing and repressurizing valves is mounted and operated within the airlock by the dome entrant.
8. A pressure relief valve set to open if the airlock pressure exceeds 16 psig, which may happen if the vent line plugs (Increased pressures

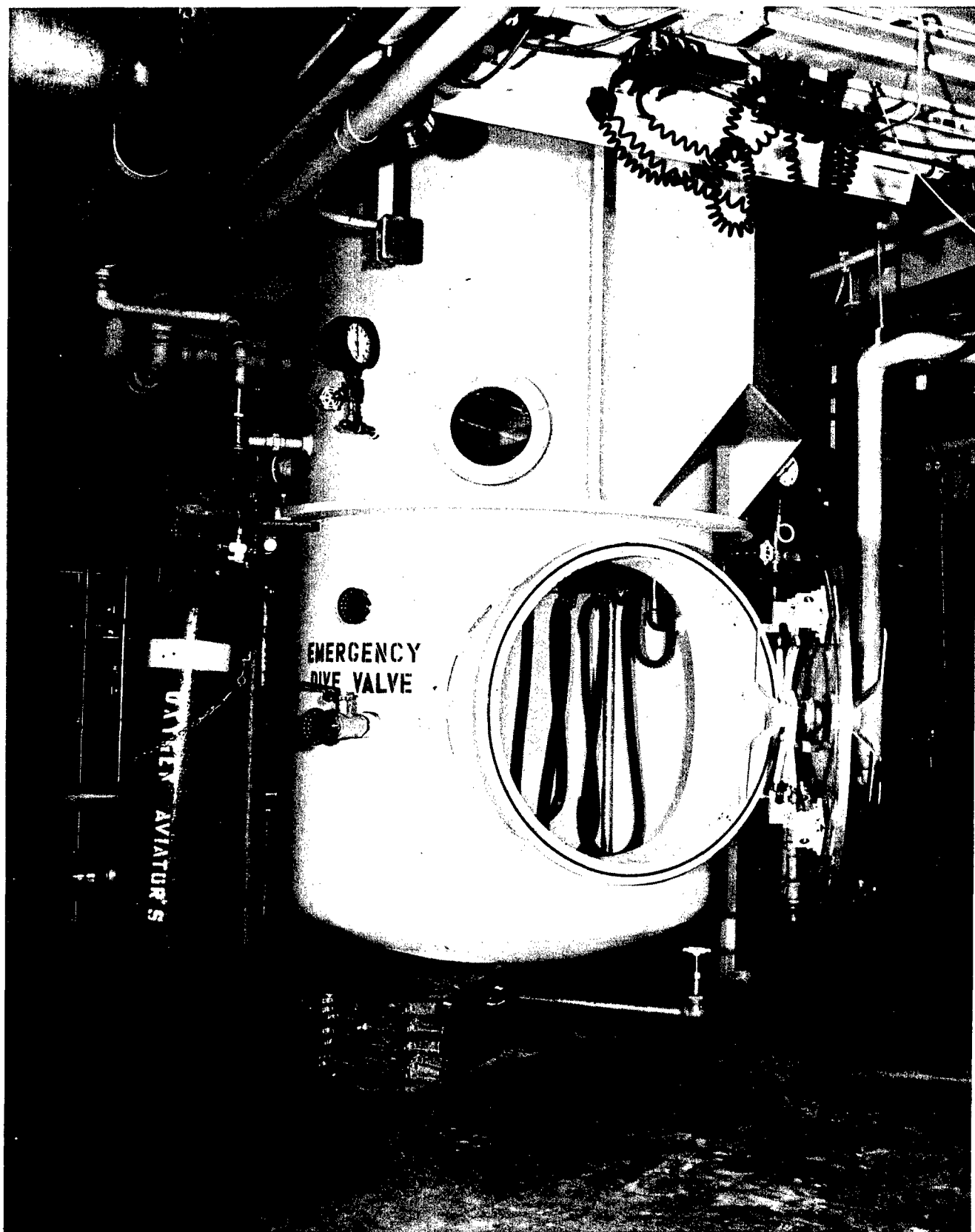


Figure 19. Thomas Dome Airlock

could arise since the gaseous oxygen airlock flushing system operates at a pressure of 50 psig.)

9. A pressure relief valve set to open at 240 mm Hg pressure to prevent over-depressurization and danger to the airlock occupant

10. A drain valve located at the bottom of the airlock

11. An aluminum grating, located about 6 inches above the drain, is utilized as the floor of the airlock.

12. A communication outlet for direct communication between the occupant of the airlock and the safety observers

13. An oxygen-demand pressure regulator for connection to the oxygen-breathing mask worn by dome entrants

SECTION IX

LIQUID OXYGEN SUPPLY SYSTEM

LOCATION

A liquid-oxygen (LOX) vaporizer system, located 15 feet south of the altitude laboratory, provides a continuous gaseous-oxygen supply for the altitude facility. The system can supply gaseous oxygen at a maximum rate of 400 scfm at 50 psig and 72°F. The equipment, shown in figure 20, is mounted on a concrete slab foundation, which is fenced in for safety purposes. A 7500-gallon liquid-oxygen storage tank feeds a liquid-oxygen pump forcing the LOX into a liquid-to-gas converter. Power to operate the gaseous-oxygen system is provided in the main electrical panel located in the basement of the altitude facility.

The liquid-oxygen converter system is regulated by an oxygen demand system that applies more or less heat as oxygen flow rates are modulated to maintain the oxygen flow to the domes at $72^{\circ} \pm 2^{\circ}\text{F}$. The liquid oxygen passes through a heat exchange column and exits as gaseous oxygen. The heat exchange medium is an equal mixture of ethylene glycol and water which surrounds five rod-type heater units that are operated by a control unit based on delivered oxygen gas temperature. The five 20 KW heaters stage in sequentially through a relay system located on the liquid oxygen pad.

GAS OXYGEN SYSTEM

Figure 21 shows the oxygen-gas supply system serving a typical airlock and dome. The following is a summary of the components and their function starting with the oxygen-gas supply:

1. A single oxygen-gas source supplies oxygen at 72°F and 50 psig to a pressure regulator serving each dome. The pressure regulator (PV-A1) reduces the pressure to 1.5 psig upstream of the hand-operated oxygen-air mixing valve. A relief valve set at 4 psig safeguards the downstream systems from over-pressurization.

2. The airlock oxygen flushing system consists of the same oxygen-gas supply flowing at 50 psig and a vent line for purging of existing air. The oxygen enters the airlock through a four-way valve tied to a three-way valve for venting the lock or for depressurization. During depressurization, the oxygen flush supply system must be manually closed by the safety

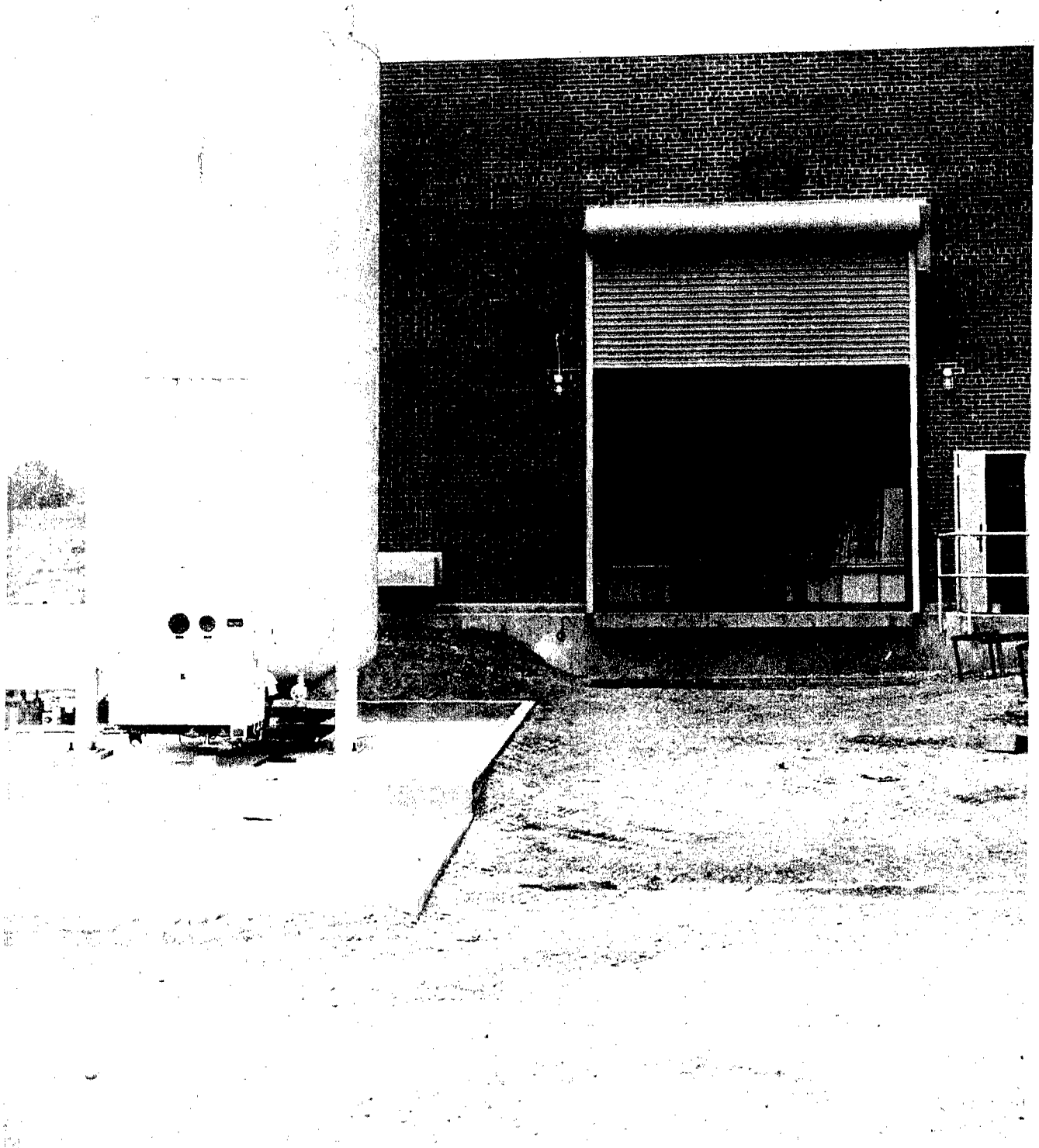
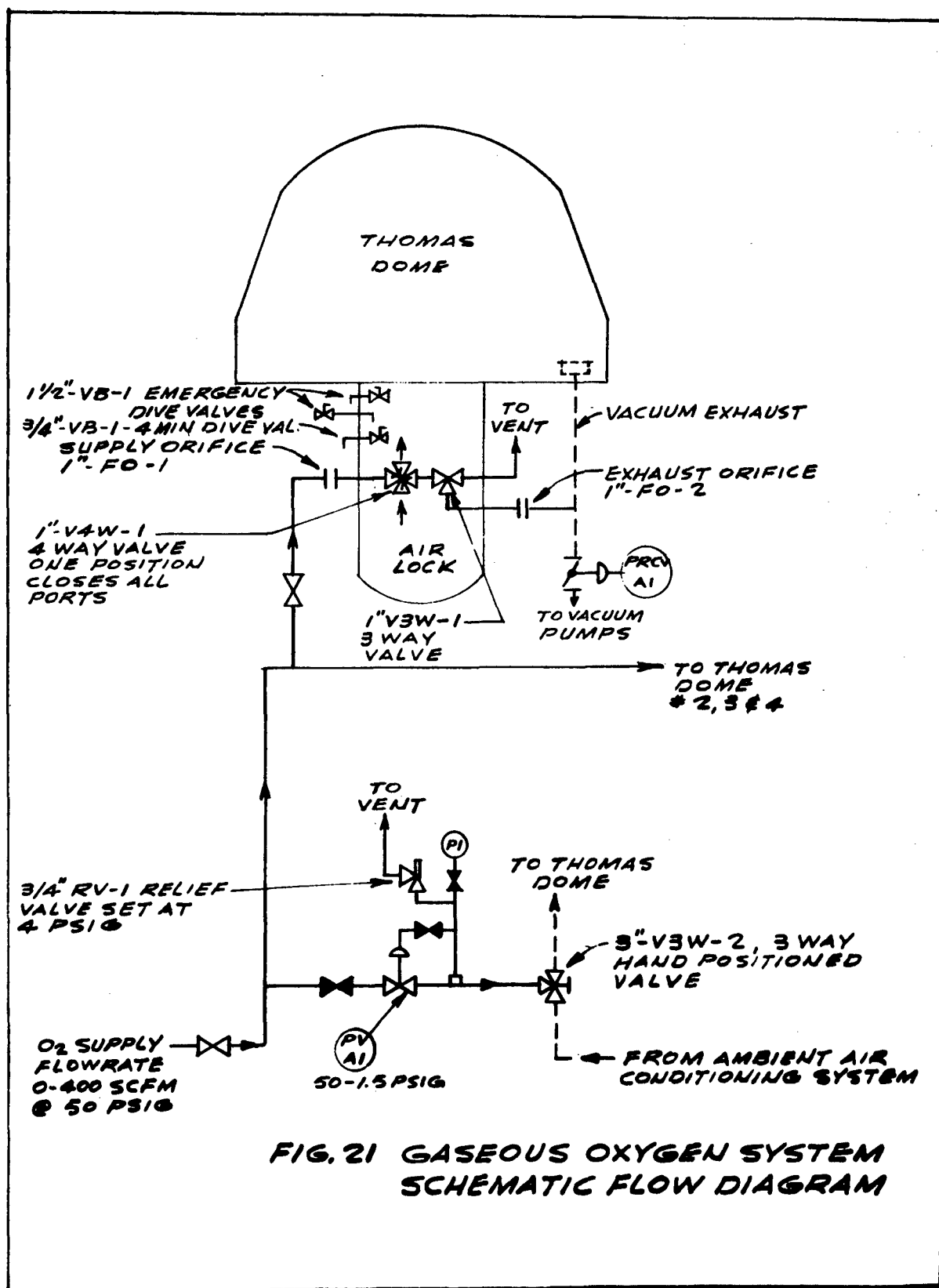


Figure 20. Liquid Oxygen Storage



observer located outside the airlock. Repressurization is effected by closing the vacuum line and opening a rate-limiting orifice valve which can be regulated or stopped by the airlock occupant if discomfort is experienced.

Emergency dive valves, operable from either inside or outside the airlock, are provided for rapid repressurization in the event of a fire or an incapacitation of the chamber technician within the lock.

LIQUID OXYGEN ALARM SYSTEM

The LOX system provided for generation of oxygen for the dome facility requires instrument air for the temperature-regulating equipment. Instrument air at 100 psig pressure is supplied with an expansion tank at the exit from the building to trap out moisture in the air. The system then leads to the pneumatic temperature control equipment located on the LOX pad.

Alarms are provided for an indication of pump failure and also for low heat exchanger temperature. The circuit activates an alarm horn and reset button located inside the altitude laboratory near the south door.

SECTION X

REDUCED PRESSURE LABORATORY AIR SUPPLY AND CONDITIONING SYSTEMS

AMBIENT AIR SUPPLY SYSTEM FOR DOMES

The ambient air supply system, using either air or an air-oxygen mixture when the domes are operated at 14.7 psia, was designed to provide clean air at 72°F to the four domes at flow rates ranging from 18 to 100 cfm per dome. Figure 22 illustrates the airflow pattern from the intake point to the manual oxygen-air mixing valve. The following is a summary of the components and controls shown in that diagram:

1. Air enters through an outside air intake and passes through a motor-operated damper. Switching on the supply air blower energizes the control circuit and automatically turns the outside air damper to a fully open position. This process is reversed when the blower is not in use. The total ambient air requirement for the four domes may vary between 72 cfm and 400 cfm depending upon specific experimental parameters such as chamber animal load and carbon-dioxide concentration. A bypass loop from the discharge side of the recool refrigeration coil recirculates the unused portion of the air drawn into the system to the suction side of the prefilter where it is blended with additional outside air to bring the total volume back to 400 cfm.
2. The incoming air first passes through a preliminary filter where at least 45% of all particles 0.3 micron and larger are removed.
3. The filtered air then passes through the preheat steam coil. A duct thermostat downstream of the preheat coil is set to maintain minimum temperature of 50°F by controlling a modulating steam valve serving this coil. This coil can heat 400 cfm outside air from -10° to +50°F.
4. The air next flows through a precooling coil, a reheat coil, the supply fan and a recooling coil. Since a high brake-horsepower (7-1/2 hp) supply fan is required to increase the air pressure from atmospheric to 1.5 psig for dome operation, an air temperature increase of approximately 45°F is produced. Consequently, the recool coil is required to control the treated supply air at 72°F for use in the domes.
5. The recool coil is followed by the recycle bypass system as previously described. The air supply ultimately sent to the domes is then passed through an absolute filter for final dust removal.

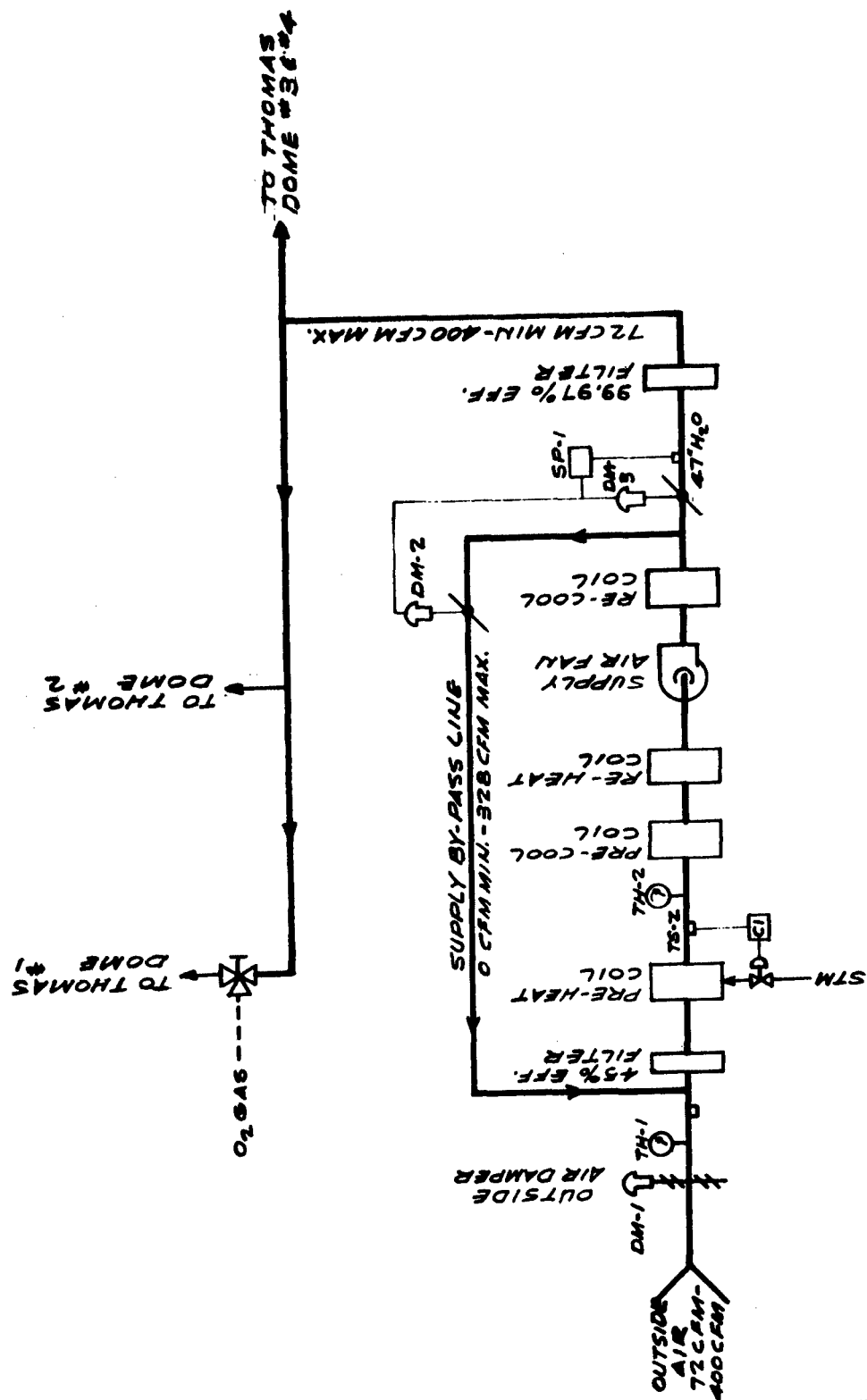


FIG.22 AMBIENT AIR SUPPLY SYSTEM
SCHEMATIC FLOW DIAGRAM

THOMAS DOME GAS FLOW SYSTEMS

The dome gas-supply system consists of the oxygen and ambient air-supply systems previously described, hand-operated mixing valves, gas-flow control valves and a relative humidity control system.

The principle of vacuum operation of the Thomas Domes, which are dynamic flow chambers, is to exhaust air at a greater rate than the inlet air flow rate. This procedure is accomplished by presetting the inlet air flow control valve at the instrument panel and then setting the vacuum control valve at the absolute pressure level desired. The vacuum pump can pull a greater vacuum than required, and the actual Thomas Dome pressure is then regulated by the vacuum control valve. This vacuum-control valve is a butterfly-type valve which modulates, through its controller, the amount of vacuum applied to the dome.

The dome exhaust vacuum system, with pressure-control and make-up air valves, normally utilizes two vacuum pumps with a third pump in standby condition. The vacuum pumps require manual changeover. Figure 23 shows the gas-flow system of a typical dome, beginning with the three-way oxygen-mixing valve and ending with the discharge line from the vacuum pumps. The sequence of operations is as follows:

1. The oxygen gas-supply system and the ambient air-supply system both provide gas at a pressure of 1.5 psig to the upstream ports of the three-way mixing valve. A flow indicator located in the ambient supply airstream is utilized to measure visually the airflow to its respective three-way mixing valve. The three-way mixing valve can be hand-positioned so that any variation in oxygen-air ratio of zero to 100% can be supplied to the dome.
2. A flow-control valve manually set at the instrument control panel will automatically control the total gas flow to its respective dome. This is accomplished by a flow recorder-controller which records air flow measured by a laminar flow element located upstream of the flow control valve. The air signal from the laminar flow element is supplied to the recorder by a differential pressure transmitter. The flow recorder-controller positions the flow-control valve to maintain the desired pressure differential across the laminar flow element which can be interpreted in terms of actual air-flow volume.
3. The steam-operated humidifier feeds an injector system mounted in the dome gas-supply line. The steam is rapidly dried by the moisture-free oxygen passing through the gas-supply system. Since the WPAFB supply of low pressure steam is not continuous during the summer,

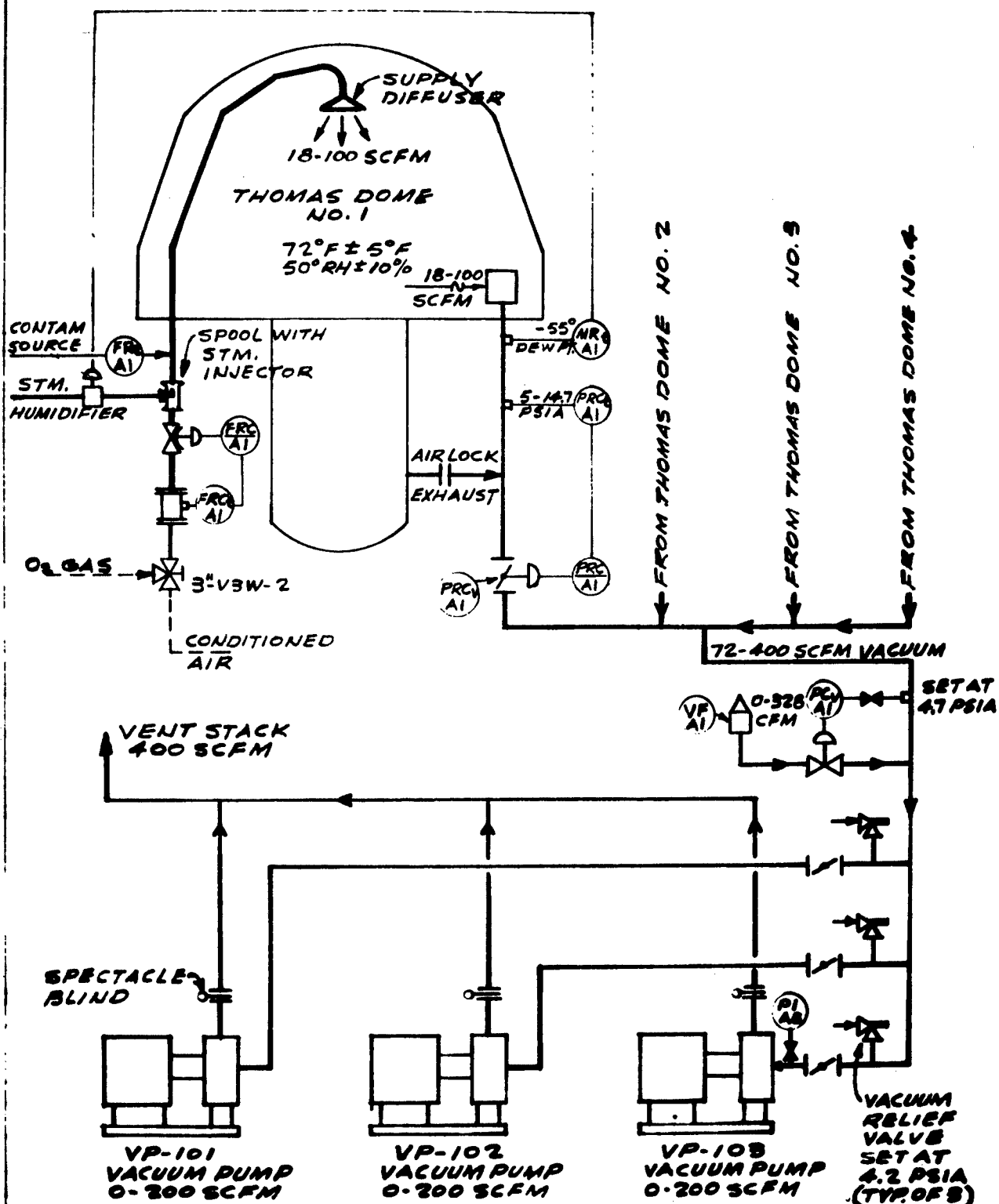


FIG. 23 THOMAS DOME GAS SUPPLY & VACUUM SYSTEM SCHEMATIC FLOW DIAGRAM

months and may add unwanted contaminants in the form of boiler amine compounds, a small independent boiler has been provided. This boiler produces steam from water passed through a commercial water-softener device.

The dome humidifier system is controlled by a dew-point transmitter and moisture recorder-controller system. The control dew point may be varied to provide 50% RH at a temperature of 72°F in the domes throughout a pressure range of 5 psia to 14.7 psia. At 5 psia, the dew point required to produce 50% RH is 27°F and at 14.7 psia, it is 55°F.

Relative humidity is commonly thought of as a function of the moisture content of air at a given temperature and can be computed from a standard psychrometric chart if dry bulb temperatures and either wet bulb or dew point temperature are known. This definition is correct but neglects the important fact that relative humidity is also a function of pressure since air at reduced pressure is unable to contain as much water vapor as the same temperature air at ambient (14.7 psia) pressure. For this reason, the psychrometric chart, shown in figure 24, is used to calculate chamber relative humidity at various operational pressure levels.

4. Contaminants are introduced into the dome gas-supply line following the flow-control valve and the modulating steam humidifier. The contaminant flow is measured by a differential pressure flow meter.

The contaminant-containing air mixture is then diffused through the dome by an anemostat which is preceded by a double set of baffles to insure good gas-contaminant mixing.

Contaminant distribution studies conducted within the domes at various positions around the domes and at different heights have shown that reasonably uniform gas distribution results from the contaminant introduction and airflow design-pattern parameters.

The sampling results shown below were obtained manually within the domes. These grab samples were collected in tonometers which were brought out of the chamber through the airlock and immediately analyzed.

<u>Dome Sampling Point</u>	<u>Contaminant Concentration (ppm)</u>		
	<u>O₃</u>	<u>NO₂</u>	<u>CCl₄</u>
Ceiling East	3.4	15.7	12.3
Floor West	3.4	14.1	13.2
Ceiling South	3.6	15.5	14.3
Floor Center	3.8	15.0	14.0

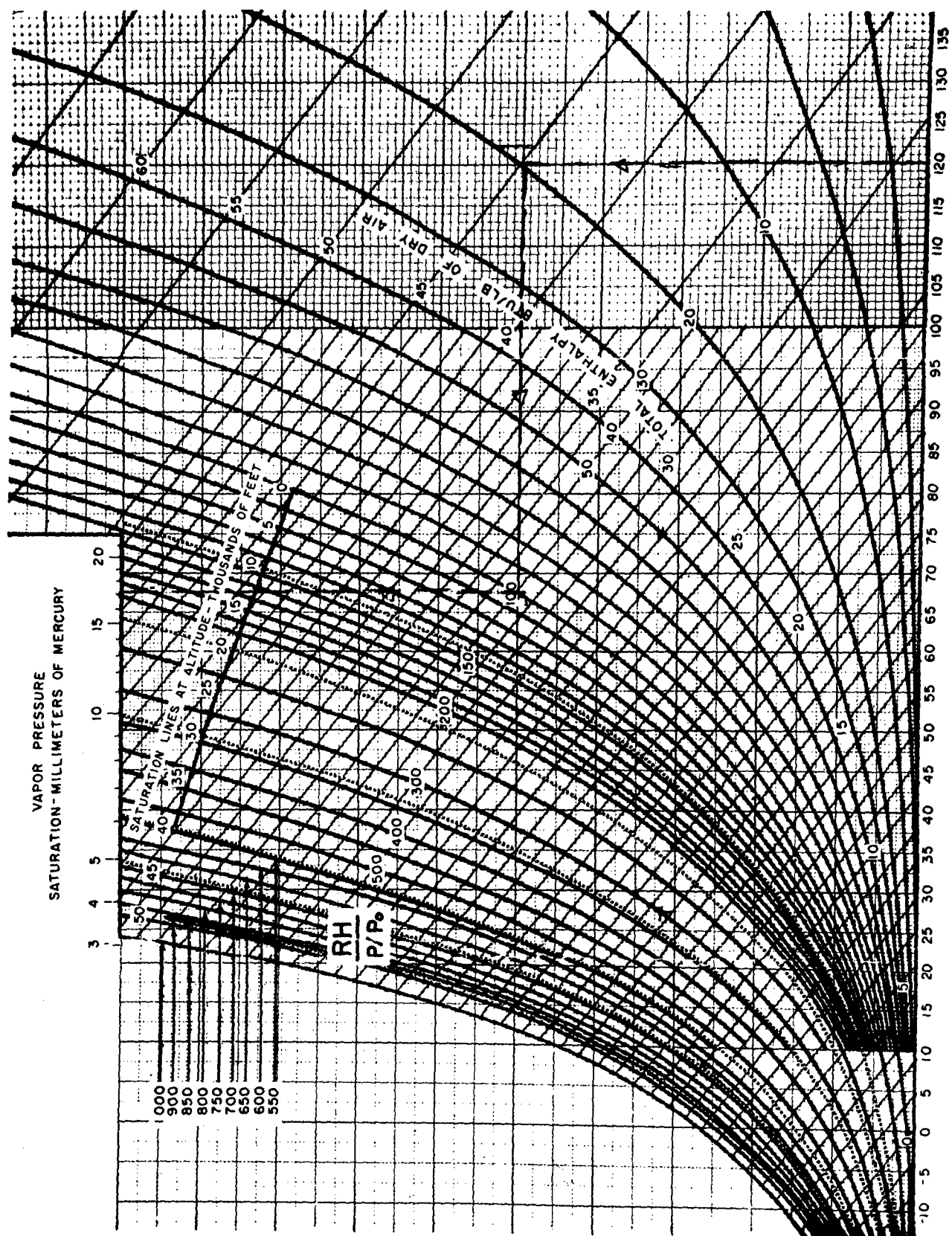


Figure 24. Psychrometric Chart for Reduced Pressure

5. The dome is exhausted through an annular duct which follows the internal perimeter of the bottom section of the dome. This exhaust arrangement helps to provide the even distribution of the contaminant concentration just described. An in-line filter was installed to act as a lint trap to remove animal hair or food dust which could foul the vacuum-control valve or pump. The gas continues through the pressure-control valve located in the exhaust duct, which is automatically positioned through a panel-mounted pressure recorder-controller and a pressure transmitter, to maintain a preset dome pressure variable between 5.0 psia and 14.7 psia as previously mentioned.

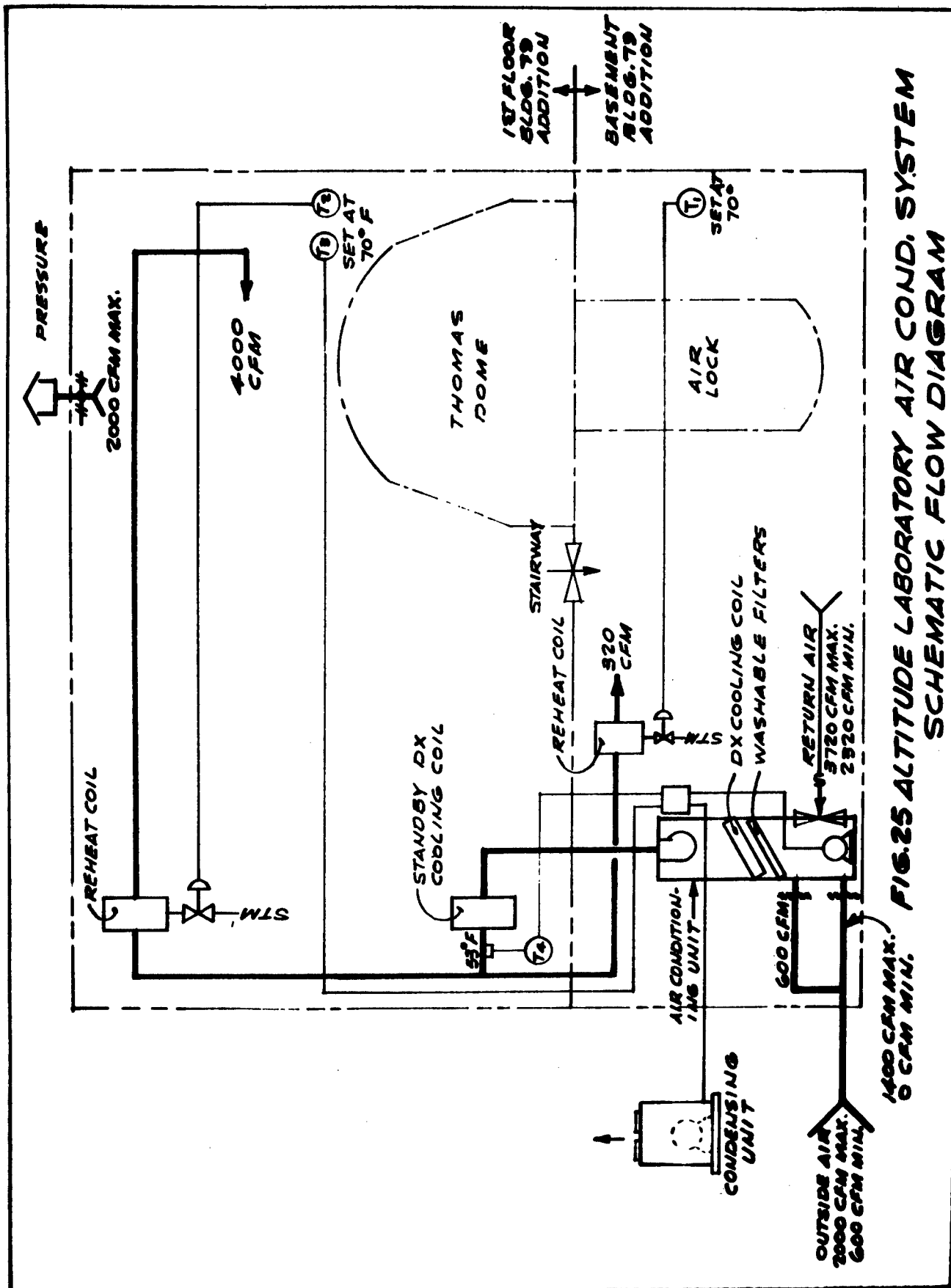
6. The combined effluent gases from all four domes are then drawn through any pair of three available vacuum pumps and discharged through a common vent above the building roof line. If airflow to the vacuum pumps drops below a preset minimum flow when they are operating, a relief valve in each vacuum pump set at 4.2 psia will open. This relief valve prevents a pump from operating below its safe limit of 4.0 psia at the air volumes required.

The pressure in the suction header to the pumps is controlled at 4.7 psia by a self-contained pressure-control valve with a pilot operator for fine control. This valve allows outside air to enter the filter and provide make-up air if the dome effluent gas does not total the 400 cfm combined operating capacity of the two vacuum pumps.

GENERAL LABORATORY AIR-CONDITIONING SYSTEM

As mentioned previously, the room area surrounding the domes must be controlled at $70^{\circ} \pm 2^{\circ}\text{F}$ for radiant cooling or heating of the dome interior. The cooling is accomplished with a self-contained air-conditioning unit located in the basement. Since this temperature control is critical, a standby refrigeration loop located outside the building is tied in with this system and can be manually switched on.

Figure 25 is a schematic diagram of the air-conditioning system serving to maintain a temperature of $70^{\circ}\text{F} \pm 2^{\circ}\text{F}$ in the Reduced Pressure Laboratory. No attempt is made to control the relative humidity of the general laboratory at a specific level. However, the design criteria were calculated to prevent an excess of 55% RH during the most humid weather conditions. This system provides an air flow of 2000 cfm, equivalent to four air changes per hour, which is a satisfactory air exchange rate for temperature control. Contaminant leakage from the dome does not constitute a hazard, because these chambers are operated at vacuum conditions



**FIG. 25 ALTITUDE LABORATORY AIR COND. SYSTEM
SCHEMATIC FLOW DIAGRAM**

and are never pressurized. The following is a summary of the components and controls in the system, starting from the fresh air intake and ending at either return-air or exhaust discharge points.

1. Outside air enters the self-contained air-conditioning system through two manually-operated dampers. When both dampers are fully open, 2000 cfm enters the system. When the larger damper is fully closed, 600 cfm of fresh air enters the system.

During periods of extreme heat, the large damper should be closed to permit partial recycling of the air and to permit the air-conditioning unit to maintain the desired room temperature.

2. The outside air mixes with return air and is filtered through washable-type filters.

3. The air is then cooled by a direct expansion-type cooling coil to 53°F controlled by a duct thermostat. This control temperature is necessary to remove sufficient moisture from the air so that, at normal personnel occupancy, the supply air can handle the personnel-moisture load and limit the relative humidity of the room air to not more than 55%. If the self-contained refrigerant circuit is out of order, a standby coil and its refrigerant circuit is manually switched into operation until the first system is repaired. The compressor unit feeding the standby coil is located immediately outside the south wall of the Building 79 addition.

4. After passing through the standby coil, located downstream of the supply-air fan, the air is diverted into two main ducts. One duct serves the basement area and the other the dome room.

5. Each main airstream passes through a steam reheat coil which is operative during the winter months. A thermostat in each zone controls a steam-modulating valve feeding the individual coils to maintain $70^{\circ} \pm 2^{\circ}\text{F}$ in their respective control zones.

6. The general room air supply is relieved through a pressure relief damper and exhaust duct located in the ceiling of the reduced pressure laboratory. The remaining air returns through the stairwell to the basement and into the return grill on the face of the air-conditioning unit.

7. During the summer months, the WPAFB steam supply system serving Building 79 is normally shut down for a two- to three-week period for maintenance. During this period there is no steam available for reheat control; therefore, a secondary thermostat has been provided which is actuated by a pushbutton controlling an electrically-operated pneumatic relay.

This relay bypasses the duct thermostat-control circuit. This auxiliary thermostat then directly controls the refrigerant coils and supporting refrigeration components to maintain the temperature within the altitude laboratory at the desired level.

REDUCED PRESSURE LABORATORY CONTROL PANEL

The primary control and operation of the Reduced Pressure Laboratory is centralized in the master control panel. This control panel, shown in figure 26, is composed of four modular units, each module containing the recorder-controllers and alarm systems for an individual dome. Alarm horns are located in the dome room, basement, Ambient Pressure Laboratory and office area of the building. The recorder-controller units have been equipped with manual overrides for emergency isolation of the domes. Six recorders, mounted in each control module, are as follows:

1. A two-pen recorder for the monitoring of carbon-dioxide and oxygen concentrations within the dome. This recorder has been provided with a low alarm signal for oxygen partial pressures and a high alarm signal for increased carbon dioxide concentrations.

2. Contaminant-Flow Recorder:

This recorder continuously monitors the flow rate of contaminant to the atmosphere supply line serving an individual dome. It is equipped with both high and low alarm signals.

3. Gas-Flow Recorder:

This recorder measures the volume of air or oxygen or the mixed gas entering each dome as sensed by the laminar flow element previously described. Since an increased flow would not constitute a serious problem, the recorder has been equipped only with a low flow alarm.

4. Absolute Pressure Recorder:

This recorder indicates the absolute pressure in the individual dome and is equipped with a high alarm signal. A signal from this alarm would indicate that the pressure was rising from the preset experimental parameter toward ambient pressure, and would be indicative of either vacuum pump failure or a major leak within the dome. A low pressure alarm was not included in this system because pressure relief valves are set to open when the pressure drops below 230 mm Hg within the dome. The noise created by the opening of the relief valve would serve as adequate warning to the chamber operator that a problem existed and required correction.

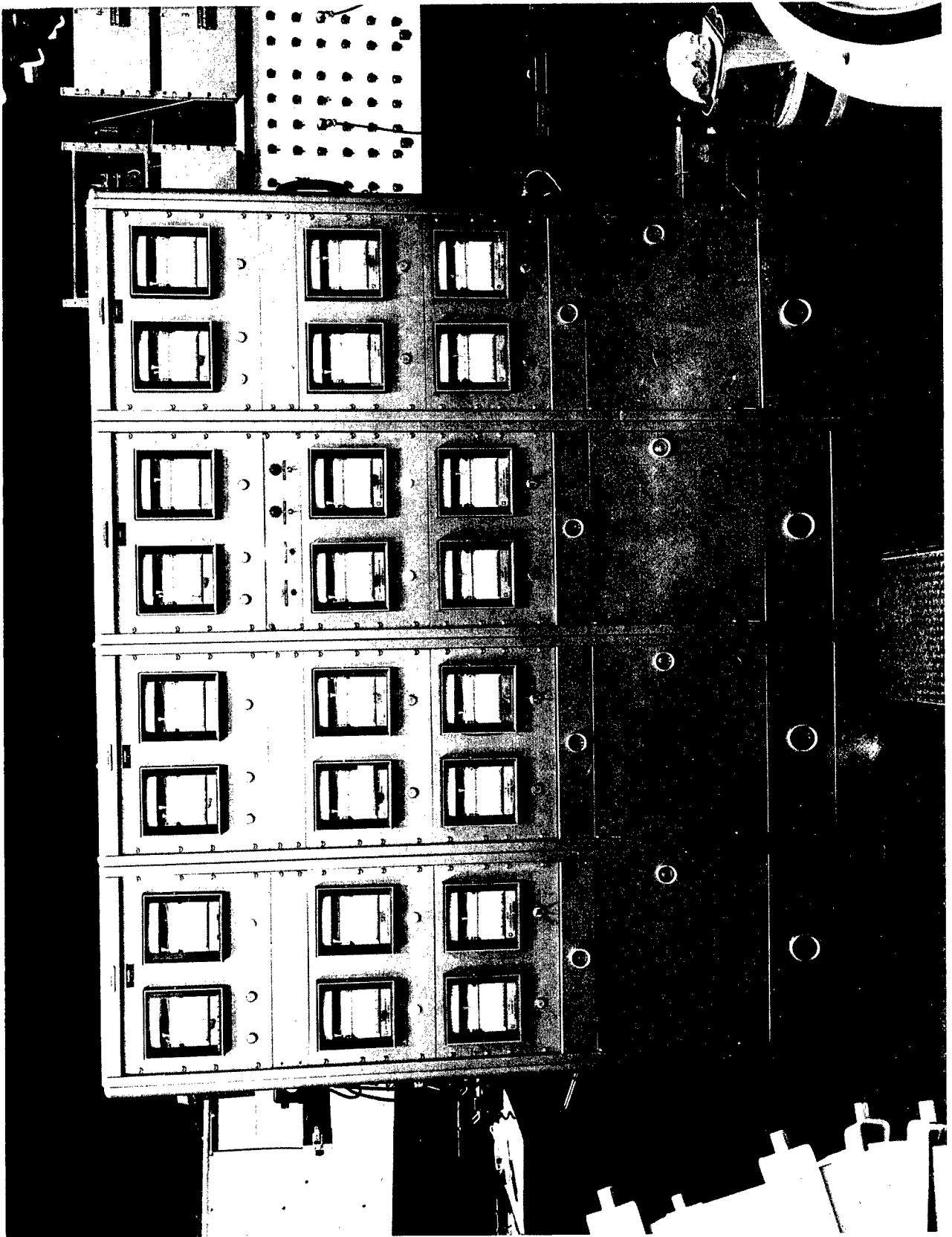


Figure 26. Reduced Pressure Laboratory Master Control Panel

5. Temperature Recorder:

This strip chart recorder gives a continuous tracing of actual temperature within the dome. A sensing probe is located in a penetration on the side wall of the lower section of the dome. It is equipped with both high and low temperature alarm signals.

6. Moisture Recorder:

This recorder provides a continuous record of the dew-point temperature within the exhaust line of the dome and controls the modulating steam valve to regulate relative humidity as required. Since this parameter is not as critical as the previously described systems, no alarm was provided.

The recorders and their alarm signals are monitored by the chamber operator and readings are recorded in a daily shift log at half-hour intervals. This action is taken to prevent experimental loss in the event of instrumental failures.

SECTION XI

DOME LIFTING AND SUPPORT EQUIPMENT

DOME LIFTING

As previously described, the Thomas Domes were designed with a removable top section. This top section of the dome may be removed for dome repair, loading of animals and equipment between experiments, and for emergency purposes in the event of personnel injury during dome entries. A 5-ton bridge crane has been installed on a movable track over the four domes and can be positioned over each dome individually. This crane has an automatic, electrically-operated button control system for raising or lowering the dome.

SUPPORT STANCHIONS

When the dome lids are raised to permit cleaning or loading of animals prior to initiation of new experiments, specially designed dome supports are used which were obtained to provide maximum safety for personnel. Figure 27 shows a dome supported by five of these stanchions which are held in place by 1-inch bolts at each end through matching holes in the dome top and bottom section flanges. A set of dome support stanchions has been provided for each dome so that maintenance work may be conducted on the four domes simultaneously.

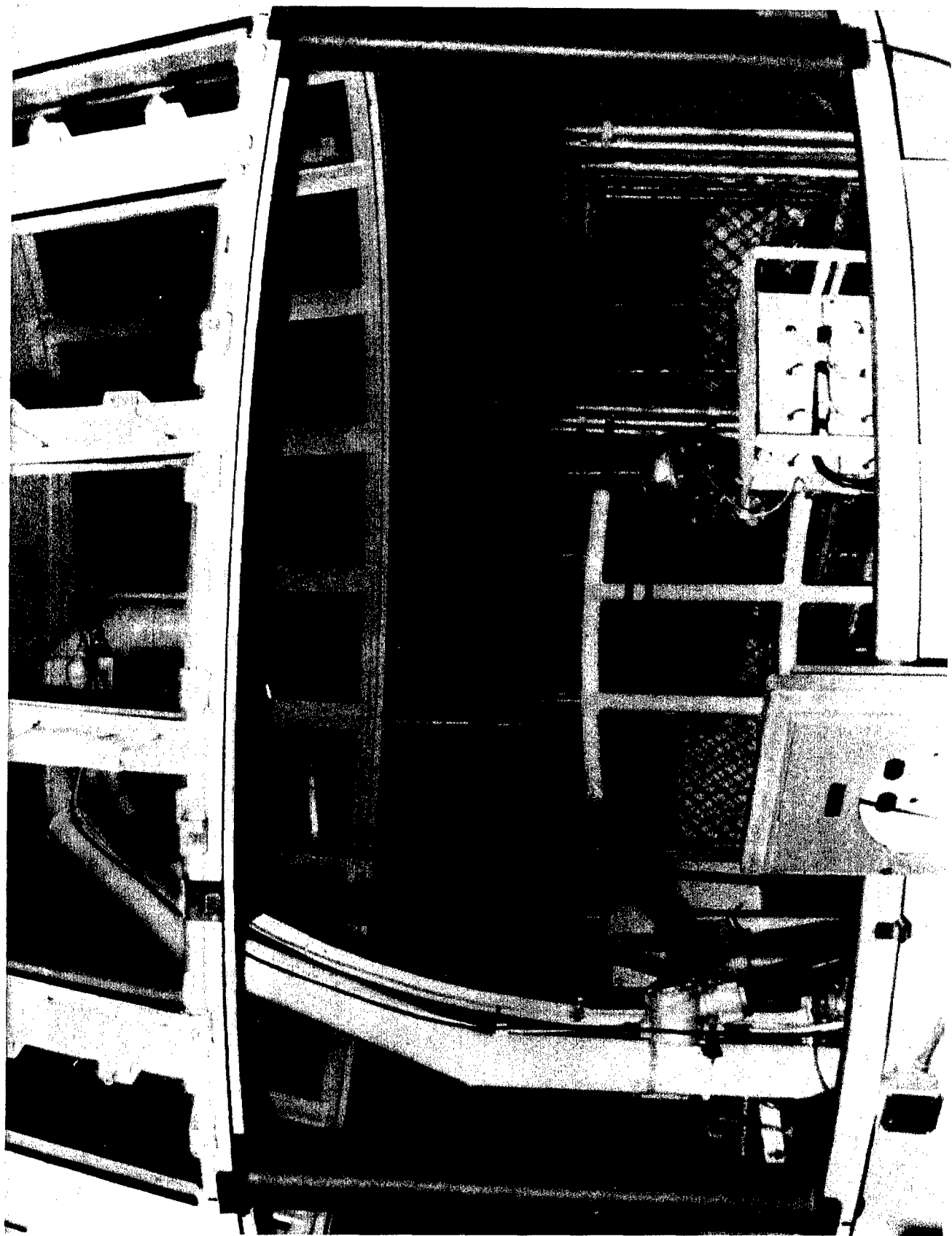


Figure 27. Thomas Dome Support Stanchions

SECTION XII

DOME COMMUNICATIONS

INTERCOMMUNICATION SET

A communication system was installed in the domes to provide direct and continuous communications between dome entrants and the safety observers. The system originally used in the facility utilized two Air Force control stations, Model C823, which were a part of the standard AIC-10 intercommunications system. This system proved inadequate because of the number of stations in use; therefore, a transistorized 12-volt DC amplifier was installed to provide communications from battery power in case of emergency. The amplifier installed is a 25-watt system.

The communications system consists of stations in individual airlocks with plug jacks for three dome occupants. The chambers are provided with the same number of plug-in units. Stations are set up for communication with the safety observers outside of each airlock, in the prebreathing station, outside of each dome and at the control panel.

An attempt is currently being made to obtain a complete Air Force communications system of AIC-10 type to provide better communications between dome occupants and the safety observers. A backup system in communications has been provided for use should there be power failure. Two walkie-talkie type units are used for communication between the dome occupant and one safety observer. One of these units is to be taken into the airlock by the dome entrant as a routine safety procedure.

INSTRUMENTATION SIGNAL LINES

A system was designed and installed in the domes to provide instrument signal lines for future use. Twenty-four shielded cables connected through the dome penetration plate by special sealed Cannon plugs transmit signals between a terminal panel mounted in each dome and a master panel mounted in the altitude laboratory beside the control console. This system is intended for use in the monitoring of physiological parameters by instrumentation located in the general laboratory area, thereby reducing the total amount of equipment required inside the dome during research experiments. Among the parameters which can be measured on laboratory animals or human subjects are electrocardiograms and electroencephalograms.

SECTION XIII

SAFETY REQUIREMENTS

DESIGN CONSIDERATIONS

Both during the design stages and in the planning for the actual operation of the Reduced Pressure Laboratory primary attention was given to the conditions and procedures necessary to insure the safety of the dome entrants.

Prior to the exposure of the first human to altitude conditions (100% oxygen at 5 psia pressure) in the domes, the following regulations were transmitted to Aerojet-General Corporation by the Air Force. Strict compliance with these regulations was a contractual requirement.

SAFETY PROCEDURES FOR OPERATION of THRU ALTITUDE CHAMBERS

1. General - The biggest danger connected with experiments in a 100% oxygen atmosphere is the problem of fire. Generally speaking, the kindling point of a substance is not materially changed; however, the speed of combustion is increased at least fivefold. Because these studies are to be done at an atmospheric pressure of 5 psi (260 mm Hg), bends could be a problem. There are numerous and sundry medical emergencies which cannot be predicted and which could occur irrespective of the test. There must be emergency equipment on hand and a physician on call. Only one chamber shall be occupied at any time.

2. Fire Hazard - Flammable materials should be kept from the chamber unless essential to the experiment. Personnel entering the test chamber must wear cotton clothing and rubber shoes to minimize problems from static electricity. In case of fire, immediate recompression of the chamber at the fastest rate must be accomplished. The overhead crane will be attached at all times to the top of the chamber in which the person is working in order to remove the chamber top for rescue work.

3. Bends - To decrease the incidence of bends, personnel will denitrogenate for thirty minutes before entering the chamber. After entering the lock, pure oxygen will be breathed until the 100% oxygen atmosphere of the chamber is reached. It is then permissible to remove the mask. If bends occur during activity in the chamber, the occupant shall descend into

the lock and leave the chamber immediately. In the event of incapacitating bends, the chamber shall be recompressed at a rate of 0.5 psi/second. Incapacitating bends are described as those of such a severity that the person is unable to leave the chamber under his own power or that he is unconscious.

4. Recompression - The chamber will be recompressed under emergency conditions (except fire) at the rate of 0.5 psi per second or slower. This means a twenty (20) second recompression time for the chamber. In case of fire, recompression will occur as rapidly as possible.

a. All equipment shall be firmly anchored to the structure to prevent flying debris in case of rapid decompression.

5. Crew - One crewman will be continually monitoring chamber atmosphere during human habitation with means to correct any altered components or pressure of the chamber atmosphere. There will be manual overrides for all automatic systems.

a. There must be an outside observer for the man in the lock and in the chamber. This can be the same person. During the observer's transit from the basement to the operating level, the atmosphere monitor can observe the person in the chamber. The outside observer can also enter the chamber to assist an incapacitated inside technician. There will be continuous provision for visual and audio communication among observers, monitors and inside technicians.

b. A physician will be on call at all times humans are exposed to the experimental environment.

6. Emergency Equipment - A pulmonary resuscitator and a defibrillator-pacemaker will be near the chamber for emergencies. Standard medical examining equipment and appropriate drugs will be available. Such equipment and drugs will include, but not be limited to:

- a. Isotonic (5%) Dextrose for I. V. infusion - 2 liters
- b. Isotonic Saline for I. V. infusion - 2 liters
- c. Sodium Bicarbonate - 50 meq - 3 ampules
- d. Sterile I. V. infusion sets - 3
- e. Disposable 21-gauge needles - 20
- f. Adrenaline 1:1000 for injection
- g. Levophed - 6 amps
- h. Calcium Chloride - 3 amps
- i. Sphygmomanometer and Stethoscope
- j. Sterile 21-gauge lumbar puncture needle (for intracardial injection)

- k. Laryngoscope
- l. Cuffed intratracheal tube
- m. Sterile syringes
 - 1. 25 cc - 2
 - 2. 10 cc - 5
 - 3. 5 cc - 5

7. Exposure and physical condition

a. All personnel entering the test chamber under test conditions (5 psi; 100% O₂) shall have passed a Class III physical examination and successfully completed the passenger instruction phase of physiological training as described in Air Force Regulation 50-27.

b. Personnel entering the chamber will be responsible for reporting any soreness or discomfort of the ears, nose, throat or sinuses to the physician on call. Conditions which prohibit flying shall also prohibit exposure to reduced pressures.

c. Exposures to altitude will be limited to a series of four (4) ascents and descents per 24-hour period, with a one (1) day interval between the series of exposures. (5 psi; 100% O₂)

d. Exposure to toxic materials will be below the TLV (Threshold Limit Value).

8. Post-run symptoms - Otitis media will probably be the primary post-exposure complaint. This is caused by a decreased middle ear pressure, due to the absorption of oxygen from the ear. Equalization of pressures normally alleviates symptoms. Personnel in the lock shall perform the Valsalva maneuver as required during descent in order to equalize pressure in the middle ear with ambient pressure.

9. Records - The contractor or agency responsible for the operation in the chambers will maintain complete medical records including, but not limited to, subject's name, date of run, time in chamber, subjective sensations and personal comments, and environmental chamber conditions.

Items 2, 3, 4, 5, 5a, 8 and 9 are integral parts of the standard operating procedures which are presented in the next section of this report.

In regard to items 1, 5b and 6, the emergency equipment is maintained within a laboratory of the THRU whereas medical personnel are on call at all times. During duty hours, Drs. Thomas and Harper of the Toxic Hazards Branch may be available; and if not, the Area B dispensary can be

notified. During nighttime hours, the emergency room of the WPAFB Hospital, Area C, maintains an ambulance service. Telephone numbers of both the dispensary and the emergency room are posted in the reduced pressure laboratory and the medical personnel of both facilities have been alerted to both the possibility of an emergency call and the probable nature of the injuries to be expected.

To satisfy the regulations listed under item 7, the following measures have been taken:

1. A local physician has been contracted to screen all applicants for employment by subjecting each to the Class III physical examination. Upon successful completion of the examination, applicants further must successfully complete the passenger instruction phase of physiological training as described in Air Force Regulation 50-27 which is presented by the Physiological Training Branch in Area B.

2. Personnel entering the dome sign a Health Status Report stating that they have not noticed any ill effects resulting from their last dome entrance, and they do not presently have any symptoms of a nature which would prevent their undergoing pressure changes within the dome.

3. A sufficient number of personnel are on call, and a posted schedule of dome entrants is maintained so that exposures to altitude are limited to a series of four ascents and descents per 24-hour period with a one-day interval between the series of exposures.

4. Full-face Scott Air-Pak Masks are employed whenever personnel enter a dome in which the contaminant concentration is above the Threshold Limit Value.

SECTION XIV

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE FOR THOMAS DOMES

The following discussion concerns the operating procedures required for entrance into the Thomas Domes when operating at reduced pressure using 100% oxygen supply.

These procedures cover the duties and responsibilities of the safety observers as well as the personnel entering the dome.

Denitrogenization

A Health Status Report shall be completed by personnel preparing to enter the reduced pressure exposure domes prior to initiation of the depressurization.

All personnel entering the domes shall prebreathe pure oxygen for a period of not less than thirty (30) minutes prior to depressurization. Regular Chamber Attendants shall prebreathe oxygen for a period of sixty (60) minutes prior to dome entry when the duration of dome entry is to exceed ten (10) minutes. Specifically, if entry is to be made for the retrieval of dead animals or equipment only and if the amount of exercise is to be kept minimal and the total exposure is to be less than ten (10) minutes, then the thirty (30) minute prebreathing period would be applicable.

Denitrogenization is accomplished by prebreathing either within the airlock or in the clothing change room by placing oxygen masks over the face and connecting the hose to the A-14 pressure regulator. Upon completion of the prebreathing period when performed in the change room, personnel shall disconnect the air line from the regulator and connect it to the walk-around oxygen bottle. The bottle shall be carried into the airlock and used until the oxygen-purge operation is completed. If denitrogenization is carried out in the airlock of an individual dome, the oxygen purging operation of the airlock may be conducted simultaneously. The purge period normally requires 15 to 20 minutes and should be started at an appropriate time prior to completion of the prebreathing period.

Clean flame-retardant coveralls should be worn in place of street clothes in each dome. When removed, the coveralls shall be placed in the appropriate storage container. The oxygen-saturated coveralls shall not be

worn out of the dome area into a smoking area with one exception. Female employees entering the dome will be permitted to wear their coveralls to the ladies' restroom to change into normal clothing. The oxygen-saturated coveralls must then be returned immediately to the storage containers in the dome area.

Exposure to reduced pressure shall be limited to a series of 4 ascents and descents per 24-hour period, with a 1-day interval between each series of exposures.

Personnel entering the chambers shall record their names, the number of ascents and descents, the date, total chamber time, subjective sensations and chamber operating conditions in a permanent log book located at the control panel immediately after leaving the last dome.

Observers' Duties and Stations

1. One observer shall be stationed at the dome control panel at all times when personnel are in the airlocks or in the domes. This observer shall be designated as Observer A. The second observer, designated as Observer B, shall be stationed beside the airlock during the operational periods when personnel are in the lock.

2. Observer A shall be responsible for connecting the crane to the dome top prior to entry of personnel into the airlocks. Whenever personnel are in the domes or the airlocks, this observer shall watch the control panel for alterations in operating conditions. The most important changes to be contended with are pressure excursions and oxygen concentrations. Observer A shall be responsible for the chamber duties described in Duties of Observer A (Day Shift).

Should power fail or there be any other emergency, Observer A shall immediately close the vacuum and airflow valves to seal the dome and prevent accidental repressurization. When personnel enter the dome from the airlock, this observer shall take over visual control and communication from Observer B until Observer B takes his station at the side of the dome. If a power failure occurs when personnel are in the dome, they shall be advised to remain quiet until emergency power is established or until notified to leave through the airlock. Observer B shall be notified to take over all observer duties during this time. Observer A shall carry out emergency procedures for power failure as shown in Emergency Procedure for Power Failure. Observer A shall make the switchover to the emergency generator and then call Base Civil Engineering for emergency service.

Should there be illness or fire in the dome and self-rescue for personnel is impossible, Observer A shall shut off oxygen flow and open the emergency dive valve. As soon as the dome is repressurized, he shall raise the dome top while Observer B contacts the WPAFB Hospital Emergency Service. If such an emergency occurs during a power outage and the dome top cannot be raised, the dome shall be repressurized and both observers shall remove personnel through the airlock.

3. Observer B shall be in voice and sight communication with personnel in the airlocks at all times. He shall notify the airlock occupants to monitor oxygen concentrations and shall receive reports of those concentrations from the occupants. Observer B shall close the external oxygen-supply valve at the beginning of the depressurization period and shall monitor the vacuum gauge to verify altimeter readings giving periodic reports to Observer A and the airlock occupants. When personnel in the airlock enter the dome, Observer B shall pass control of the occupants to Observer A and take a station on the main floor where he can continue to monitor the activities within the dome. Observer B shall return to the basement and monitor the repressurization phase until personnel leave the airlock for the general room area. He shall make appropriate notations on a form entitled Check List for Chamber Observer B. This check list shall be dated, signed and attached to the daily log sheet.

It shall be the responsibility of Observer B to see that the Health Status Report is filled out by chamber entrants and is completed by himself, making the appropriate observations. This form shall also be attached to the daily chamber logs.

Operational Sequence

The operational sequence for personnel entering the chambers shall be posted prominently both inside and outside of each airlock. This sequence is as follows:

1. Oxygen Purge
 - a. Close hatch.
 - b. Turn valve B to vent.
 - c. Turn valve A to oxygen.
 - d. Flush until sensor indicates 100% oxygen.
2. Depressurization
 - a. Turn valve B to vacuum.
 - b. Have observer close oxygen supply.
 - c. When observer signals equal pressure, open dome hatch.

3. Repressurization
 - a. Close dome hatch.
 - b. Put on face mask and connect to oxygen supply bottle.
 - c. Close valve A.
 - d. Open valve C.
 - e. When observer signals equal pressure, open hatch.

Time of Entry in Chambers

It is anticipated that all normal service functions, such as animal care and testing, shall be performed during the regular working day when medical officers are on duty either in Building 79 or at the Area B dispensary. Should entry into the domes be required at night for removal of sick or dead animals, personnel from an Air Force panel shall be called to conduct these functions. Two persons shall be required, one to serve as Observer B and one to enter the chamber. Observer A shall be the regular shift chamber operator.

DUTIES OF DOME ENTRANT

1. Report for duty at 0730.
2. Sign out oxygen mask, helmet and headset from Observer A.
3. Check airlocks for food, tools, walk-around oxygen bottles, head phone, altimeter, walkie-talkie.
4. Change into flame-retardant coveralls and boots.
5. Notify Observer A through communications system when pre-breathing starts, await word from Observer A when 60-minute prebreathing period is over.
6. When entering airlock, establish clear communications with both observers.
7. Follow depressurization instructions of Observer B.
8. Report altimeter readings to Observer B every 15 seconds.
9. Change coveralls between each descent and ascent.
10. Empty residual dog food into plastic waste bag.
11. After exit from last airlock entry, change into clean coveralls for shower.
12. After shower, change into standard work clothes and return clean helmet, mask and headset to Observer A.
13. Assist Observer B in removing waste receptacle and in cleaning dome equipment (bowls, cages, etc.) and airlocks if he needs help in these duties.

14. Remember, Observer B is directly responsible for your safety. He is your supervisor during the chamber flight. Follow his instructions.

DUTIES OF OBSERVER A (DAY SHIFT)

1. Report for work at 0800.
2. Record liquid oxygen level at 0800.
3. Make readings of all panel-mounted chamber recorders at half-hour intervals and record on daily shift log.
4. Any deviations from programmed experimental plan should be corrected immediately and entered in the log. The supervisor should then be notified as soon as possible.
5. Issue all helmets, masks and headsets to authorized personnel.
6. When dome entrant leaves to begin prebreathing, turn on the communications system and note time prebreathing starts by receiving word from dome entrant personally.
7. Be prepared to isolate domes immediately, should any emergency occur.
8. Connect crane to dome prior to entry of personnel into dome.
9. Notify Observer B if sewage tank overflow warning light flashes.
10. Check for tools left behind by dome entrant before airlock is repressurized.
11. Identify dead animals received from Observer B and enter them in the Daily Animal Log at once!! Make up Form 515 (Pathology).
12. The Chief Chamber Technician or Assistant Chief Technician shall be responsible for disposal of animals during normal duty hours.
13. Under no circumstances leave your post unless properly relieved.

DUTIES OF OBSERVER B

1. Report for work at 0800.
2. Sign out two headsets from Observer A (one for use in dome room and one for use in basement).
3. Make sure that cleaning tools, food, waste bags, walk-around bottles, etc., are in airlock and ready for use.
4. Pump sewage tank down. Make sure all dome drain valves are closed.
5. Check out communications in all airlocks with Observer A.
6. Check out walkie-talkies and put one in airlock. Keep the other on your person at all times dome entrant is in the airlock or dome.
7. Place O₂ sensor in airlock.
8. Follow procedure outlined in Check List for Observer B.

9. Empty waste from each airlock into receptacle provided.
10. Take dead animals to Observer A immediately.
11. Assist dome entrant in change room (fill walk-around bottles, etc.).
12. After last descent clean airlocks thoroughly.
13. Remove waste receptacle and empty it.
14. Remove rat pans, dog pans, cages, etc., to cleaning room, and wash, steam and dry them.
15. Remember, you are directly responsible for the safety of the dome entrant at all times that he is depressurized.

CHECK LIST FOR OBSERVER B

Denitrogenization Period

1. Start Time _____ Stop Time _____
2. Elapsed Time _____ Minutes
3. Obtain health status from dome entrant and complete appropriate section.

Airlock Oxygen Flush Period

1. Check communications with airlock occupant and Observer A.
2. Close airlock drain valve.
3. Close airlock hatch after personnel enter.
4. Valve B on vent
5. Valve A on oxygen
6. Oxygen sensor at 100% O₂
7. Notify personnel in airlock to remove oxygen mask and start depressurization procedure.

Depressurization Period

1. Valve B on vacuum
2. Valve A on oxygen
3. Close external oxygen supply valve.
4. Report airlock pressure to occupants at 15 second intervals.
5. Unlock dome hatch lugs.
6. When airlock pressure reaches chamber operating pressure, notify occupants to open chamber hatch.
7. Open hatch bleed valve.

8. Notify Observer A that personnel in airlock are entering chamber and turn over direct control to Observer A.
9. Remain at airlock until Observer A reports dome occupant has entered exposure area.
10. Report to main floor auxiliary chamber observation station.

During Periods When Chamber Technicians Are in the Dome, Check off the Following Steps as they are Completed

1. Remove, wrap and identify dead animals.
2. Change rat and mice cage pans.
3. Check water bubblers in rat and mouse cages and bleed end of water line.
4. Feed rats and mice.
5. If necessary, clean monkey cages.
6. Feed monkeys.
7. Remove dirty food bowls from dog pens.
8. Clean dog pens and floors.
9. Feed and water dogs.
10. Make final check of watering devices.
11. Make cage repairs if necessary and remove tools to airlock.
12. Make final check that all dirty bowls, pans, tools, dead animals and other gear have been placed in airlock prior to repressurization.

Repressurization Period

1. Take observation station outside airlock before personnel in chamber reenter lock.
2. Report to Observer A that you are in position and relieve him of personnel control.
3. Chamber hatch closed
4. Close hatch bleed valve.
5. Valve A closed
6. Valve C open
7. Report airlock pressure to lock occupant at 15 second intervals.
8. When airlock pressure has returned to ambient, open hatch and notify occupants to come out.

Emergency Duty

1. In the event of emergency due to illness or fire in airlock, shut off oxygen-supply valve and open emergency dive valve.

2. Notify Observer A to call WPAFB Hospital.

Name of Dome Entrant _____

Signature of Observer B _____ Date _____

DUTIES OF SWING SHIFT OPERATOR

1. Make readings of all panel-mounted chamber recorders at one-half-hour intervals and record on the daily shift log.
2. Any deviations from the programmed experimental program posted on the bulletin board should be corrected immediately and the supervisor notified as soon as possible.
3. When animals are found dead in any of the domes, immediately call in the Air Force panel members on duty. While waiting for their arrival, fill walk-around oxygen bottles and place in airlock. Set the crane over the appropriate chamber and start oxygen flush when the panel members begin their prebreathing of oxygen.
4. During periods of emergency dome entry, act as Observer A in accordance with the special directives under Standard Operating Procedures for Thomas Domes. Use duty list for Observer B wherever appropriate.
5. Clean up dog bowls and dome cleaning equipment between 1630 and 2000 hours.
6. Set up all food and cleaning supplies ready for entry into each dome between hours of 1630 and 2000.
7. Clean out the airlocks and clean airlock windows between 1630 and 2000 hours.
8. Clean oxygen face masks with dilute isopropyl alcohol solution.
9. Pump down sewage tank to 25 inches of mercury and flush out dome waste lines at 1800 and 2200.

DUTIES OF GRAVE SHIFT OPERATOR

1. Make readings of all panel-mounted chamber recorders at one-half-hour intervals and record on the daily shift log. Date all charts and indicate time at 0100.
2. Any deviations from the programmed experimental program posted on the bulletin board should be corrected immediately and the supervisor notified as soon as possible.
3. When animals are found dead in any of the chambers, immediately call in the Air Force panel members on duty. While waiting for their arrival, fill walk-around oxygen bottles and place in airlock. Set the crane

over the appropriate chamber and start oxygen flush when panel members begin prebreathing of oxygen.

4. During periods of emergency dome entry, act as Observer A in accordance with the special directives under Standard Operating Procedures for Thomas Domes. Use duty list for Observer A wherever appropriate.

5. Set up cages with rats for ambient chamber chronic toxicity studies between 0600 and 0800 daily, Monday through Friday.

6. Fill all walk-around oxygen bottles and replace large oxygen cylinders prior to 0800. Mark empty cylinders with masking tape and red crayon.

7. Have sewage tank pumped down to 25 inches of mercury prior to 0800.

8. Pump down sewage tanks and drain dome waste lines at 0200 and 0600.

9. Wash any dirty rat cages standing around in the rat quarters. Leave the sinks empty and clean.

EMERGENCY PROCEDURE FOR POWER FAILURE

(To be performed by Observer A or the Swing or Grave Shift Operator)

1. Shut down pressure and airflow controllers at control panel to prevent accidental repressurization of chambers.

2. Contact Base Civil Engineering.

3. Shut off all switches on motor control panel in basement.

4. Shut off main power circuit breaker.

5. Start emergency generator.

6. Base Engineer will turn on power.

7. Turn on numbered switches in sequence at motor control center in basement.

8. Return vacuum pump to operation.

9. Set pressure and airflow controllers at standard operating conditions for each chamber.

FORMS USED FOR RECORDING AND CONTROL

The following forms were referred to under Standard Operating Procedures:

1. Daily Shift Log
2. Daily Animal Log
3. Health Status Report
4. Form 515 (Pathology)

Altitude Simulation Chamber - Daily Shift Log

Comments

AEROJET-GENERAL CORPORATION -- TOXIC HAZARD RESEARCH
Altitude Simulation Chamber - Daily Animal Log

Dose: _____		Starting Date: _____		Contaminant: _____		Nominal Concentration mg/m^3 _____		Study: _____			
Species	Sex	Number	Cage	Start Wgt.	Final Wgt.	Date Rem.	Time Rem.	Days Elapsed	Rem. By	Obs. A.	REMARKS

HEALTH STATUS REPORT

FOR

DOME ENTRANTS

NAME _____ DATE _____
(Print)

I have not noticed any ill effects resulting from my last dome entrance and I do not presently have any symptoms of a nature which would prevent my undergoing pressure changes within the domes.

Signed _____

Chamber Observer B complete the following:

The above named dome entrant has completed his assignment in (_____) chambers and has been depressurized for a total of (_____) minutes. He (has) (has not) complained of any of the following symptoms:

- ☐ Ear Block
- ☐ Joint Pains
- ☐ Sinus Pains

(Check appropriate blocks.)

Comments:

Signed _____
Observer B

CLINICAL RECORD	TISSUE EXAMINATION
SPECIMEN SUBMITTED BY	DATE OBTAINED
SPECIMEN	
BRIEF CLINICAL HISTORY <i>(Include duration of lesion and rapidity of growth, if a neoplasm)</i>	
PREOPERATIVE DIAGNOSIS	
OPERATIVE FINDINGS	
POSTOPERATIVE DIAGNOSIS	SIGNATURE AND TITLE
PATHOLOGICAL REPORT	
NAME OF LABORATORY	ACCESSION NO(S).
<i>(Gross description, histologic examination and diagnoses)</i>	

(Continue on reverse side)

SIGNATURE OF PATHOLOGIST				DATE	
	AGE	SEX	RACE	IDENTIFICATION NO.	
PATIENT'S IDENTIFICATION <i>(For typed or written entries give: Name last, first, middle; grade; date; hospital or medical facility)</i>				REGISTER NO.	WARD NO.

SECTION XV

OXYGEN PREBREATHING STATIONS

PURPOSE

As described in the Standard Operating Procedures, dome entrants are required to prebreathe oxygen for a minimum of one hour to effect denitrogenization of their blood and other body tissues.

LOCATION

Prebreathing stations have been provided in each of the airlocks and, as shown in figure 28, a prebreathing station was set up in an area of the altitude facility basement. This prebreathing room also serves as a locker room for the change of safety clothing by dome entrants. The primary prebreathing station has also been provided with a rack for storage of walk-around oxygen pressure bottles. All of the prebreathing stations are equipped with standard Air Force A-14 pressure regulators locked in the oxygen position.

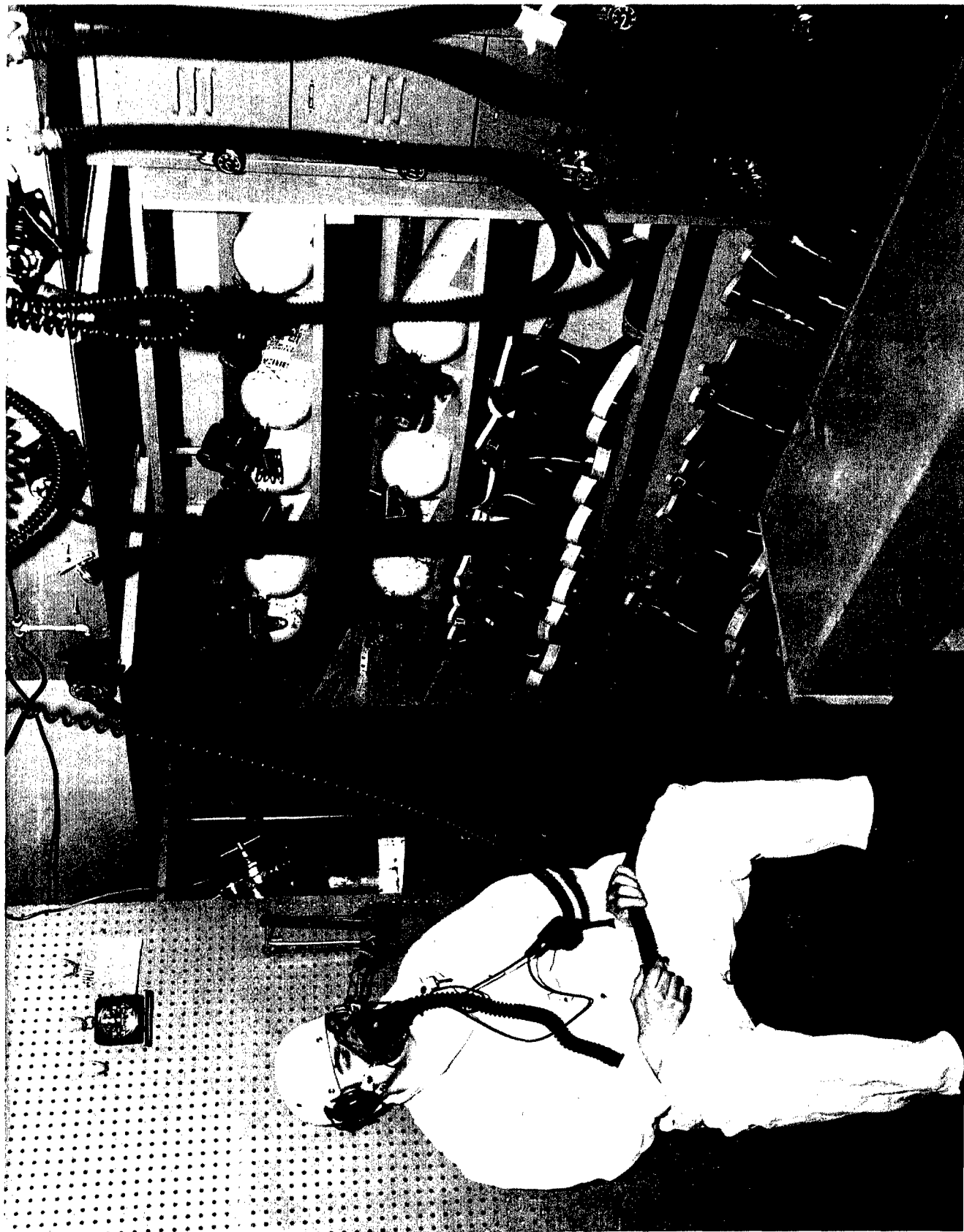


Figure 28. Oxygen Prebreathing Station

SECTION XVI

RESEARCH EQUIPMENT

GENERAL

Portions of the contaminant generation and monitoring equipment which are directly connected to the ambient chambers or the altitude domes have been previously described. However, no mention has been made of the specific contaminant generating and monitoring devices which are used in the THRU laboratory. This section of the annual report is designed to provide a brief summary of specific equipment provided for use in the THRU laboratory which is essential for conducting inhalation toxicity research.

Both government-furnished and THRU-purchased equipment are described, since all of this equipment is required for the conduct of the overall research program of the laboratory.

CONTAMINANT GENERATION

The Wright Dust Feed Mechanism

The Dust Feed Mechanism is used to produce and maintain artificial dust clouds in animal inhalation chambers. Two such units are available for use in the THRU laboratory. This instrument is compact and can be contained within a small area. It weighs approximately 7 pounds. The dust is tightly packed in a cylindrical holder. Any dust, if clean and dry and has a majority of particles below 10 microns in diameter, can be packed in this way and will form a stable cake. Yet, when the dust is scraped off the surface, it can be readily redispersed.

The dust is scraped into a groove in the surface of a scraper head. A stream of air, usually at 10 psi inlet pressure, is passed along this groove so the dust is carried down an inner tube and impacted against a plate in an orifice jet on the bottom of the device. In this manner, agglomerates are broken up, resulting in a uniform dust cloud delivered into the animal chamber.

The synchronous motor operates at a constant speed of 1 rpm in a counterclockwise direction. A large range of variable speeds may be obtained by using 4 of the set of 11 gears supplied with the apparatus.

The volumetric displacement of dust for various gear trains can be easily calculated. The calculation may be used in establishing nominal dust concentrations. The dynamics of particulate behavior are highly complex. Often the actual concentration of airborne particles attained in a chamber bears little relation to the amount of the contaminant dispersed into the supply airstream.

Mechanisms based on the design of the dust feeder have been in use in various laboratories more than 2 years, running 18 hours per day, 5 days per week and have proven extremely reliable. The Wright Dust Feeder will run for very long periods with a minimum of attention, providing the compressed air used is free of oil and surplus moisture, and the dust is sieved to ensure that it contains no large particles which would foul the outlet jets.

Dual Syringe Feeder

Five Dual Syringe Feeders, designed to provide a smooth, nonpulsating flow of liquid at constant rates adjustable from a few milliliters per hour to several liters per hour, have been obtained and are in use in the laboratory. The metering rate of this device, manufactured by Modern Metalcraft Corporation, is defined by the motor speed and gear ratios selected for use. It is used extensively in the THRU laboratory where pulsation-free liquid contaminant flows must be accurately maintained over extended periods of time.

The dual syringe feeder consists essentially of two vertically-mounted glass syringes. The syringe plungers are moved in and out alternately by rotating cams. One syringe is being filled while the other is being emptied by means of an automatically-activated four-way glass plugcock. This device was designed to discharge its liquid feed under substantially atmospheric pressure. For troublefree operation, discharge pressures exceeding 3 psig are not recommended. One of the difficulties arising when higher pressures are used is the blowing out of the valve plug; another is syringe leakage.

For the generation of liquid contaminants, the dual syringe feeder is a relatively smooth-operating, gear-driven feed device that provides uniform concentrations for prolonged periods of time and permits the use of a large reservoir of the liquid under study.

Ozone Generator

A Welsbach Laboratory Ozonator has been obtained for use in the THRU laboratory. This instrument produces ozone in quantity by the most economical method which is synthesis from oxygen in a special form of electrical discharge known as silent discharge. This ozonator efficiently produces ozone from air at a concentration of 1% by weight and from oxygen at a concentration of 2%. Higher concentrations can be achieved at a sacrifice of efficiency.

Others

In addition to the specific contamination generation systems described in the above section, a variety of auxiliary equipment has been provided by the laboratory for the implementation of contaminant generation. This equipment includes such items as liquid vaporizers and nebulizers for the dispersion of aerosols generated from salt solutions.

CONTAMINANT MONITORING DEVICES

Trace Gas Analyzer

A Billionaire Trace Gas or Vapor Detector made by Mine Safety Appliances Company is used to monitor the concentration of contaminants within the domes or other chambers. This instrument is designed for applications where it is necessary to analyze, quickly and accurately, trace quantities of a gas or vapor in an atmosphere or process stream. Certain gases can be detected in the part-per-billion range. Continuous analysis of an atmosphere or process stream for a specific component permits the necessary corrective action to be taken as soon as there is any variation from a preset operating condition. Dome atmospheres are monitored for trace quantities of generated contaminants. An automatic timer solenoid system has been installed in the equipment to switch the gas sample flow from various domes into the instrument. With the use of the solenoid switching system, several chambers can be monitored by the same piece of equipment sequentially. While the Billionaire is calibrated for 15 different materials, carbon tetrachloride and nitrogen dioxide are the only materials which have been analyzed by the THRU laboratory staff with the use of this instrument.

Oxygen Sensors

A Chemtronics Oxygen Sensor has been installed in each of the four altitude domes in the exhaust lines at the filter section. These sensors continuously monitor the partial pressure of oxygen within the dome. The sensor operates on the electrochemical principle of molecular oxygen being reduced to hydroxyl ion at a gold cathode after diffusion through a membrane. This causes current to flow in the cell which is proportional to the pressure of oxygen in the chamber atmosphere. These sensors operate continuously during experiments at reduced pressure and the electrical signal output is converted to a pneumatic signal by use of a millivolt to pressure transducer type transmitter. The transmitter sends a pneumatic signal to the altitude monitoring-control panel. This oxygen sensor is calibrated in the laboratory prior to installation within the dome and the calibration is checked periodically within the dome by use of a paramagnetic oxygen sensor. The paramagnetic oxygen sensor operates on the principle that oxygen is paramagnetic (attracted by a magnetic field) while other common gases are slightly diamagnetic (repelled by a magnetic field). If oxygen is present in a gaseous mixture, it will tend to align itself between the poles of a magnet. This rotates a quartz suspension fiber which supports a mirror reflecting a light beam upon the indicating scale. The deflection of the beam, and subsequently the scale reading, is proportional to the oxygen concentration.

Carbon Dioxide Analyzer

A Lira Infrared Carbon Dioxide Analyzer was obtained by the THRU laboratory to monitor the carbon-dioxide concentrations within the altitude domes. This analyzer is connected to an alarm system on the control panel and is preset to cause the alarm signal to sound when carbon-dioxide concentrations above 0.5% are exceeded. The Lira Analyzer operates by pumping a sample of each altitude dome atmosphere through the infrared measuring unit where the concentration of carbon dioxide is determined by absorption of infrared light at the characteristic wavelength of carbon dioxide. This unit has been provided with a sequencing system so that each dome is sampled for one minute out of four. The timing sequencing system also controls the switching of the Lira electrical output signal through a voltage-pneumatic pressure transducer to the altitude monitoring-recording panel. A separate recording is made for each chamber.

Dust Photometer

The Sinclair-Phoenix Photometer is a complete, self-contained instrument for the continuous measurement of mass concentration (dust load)

of particulate matter in a chamber atmosphere. This unit will analyze dusts through a size range of approximately 0.05 to 40 microns in diameter. The mass concentration at any given time is determined from the reading on the aerosol concentration meter or the instrument may be connected to a strip chart recorder to obtain a continuous record of the variation in concentration. The concentration is measured through an optical system which measures the forward-scattering of light from the dust particles, drawn continuously through a darkfield illumination chamber. When the physical characteristics of the particles in the test atmosphere remain relatively constant, the intensity of the scattered light is directly proportional to the dust loads and the instrument may be calibrated for this purpose.

A wide range of concentrations is measurable with this instrument by varying the attenuation. This large range is obtained on a single scale by logarithmic amplification of the photocurrent from a photomultiplier tube illuminated by the forward-scattered light. Each one-fifth of full-scale deflection corresponds approximately to a tenfold change in mass concentration. The exact relationship is determined by calibration at the factory. A standard curve is provided. The actual value of the mass concentration corresponding to a reading of the instrument depends on the physical characteristics of the dust being studied in the chamber atmosphere and must be calibrated for each material. This determination is made by measurement of the average concentration, over a suitable period, obtained by filtering and weighing the dust drawn through the chamber and deposited on a collector provided on this device. When more detailed information is desired, the collected particles may be examined microscopically.

CLINICAL AND ANALYTICAL CHEMISTRY EQUIPMENT

Infrared Spectrometer

The IR-5A is an automatic recording single-beam or double-beam instrument designed for the qualitative and quantitative chemical analysis of liquid, solid and gaseous materials. The instrument depends upon absorption of infrared radiation by molecules at wavelengths which are characteristic of their functional groups and to a degree which is proportional to their concentration. The instrument scans its wavelength range of 2 to 16 microns in 3-1/2 or 16 minutes.

Vapor Fractometer (Perkin-Elmer)

This instrument is a gas chromatograph suitable for separation and measurement of the relative concentration of components of a liquid or

gaseous mixture. There are two of these instruments available in the facility. One is used for the routine precision analysis of oxygen in the altitude domes, and the other for monitoring concentrations of contaminants in the ambient facility. The latter has the capability of flame ionization detection in addition to the normal thermal conductivity mode.

Gas Chromatograph

The Model 800 Gas Chromatograph is a sensitive instrument designed to separate complex mixtures of organic compounds with wide boiling ranges. Presently operating with an electron capture detector, the instrument also has the capability of dual flame ionization detection. The instrument has been used both for research in the investigation of complex mixtures and for control of contaminants in the chambers.

Recording Ultraviolet - Visible Spectrophotometer (Spectronic 505)

This instrument measures and records the absorption of light by solutions throughout the ultraviolet and visible range. This is useful in qualitative and quantitative analysis of solutions of complex organic and inorganic materials. It can also be used to follow catalytic and enzymatic reactions in which absorbance fluctuates.

Mass Spectrometer

The Bendix Time of Flight Mass Spectrometer fragments and ionizes the molecules of a vapor introduced into its source region. The ions formed are given an impulse of kinetic energy, and the linear velocities attained by the ions depend upon their mass-to-charge ratio; the particles which have the smaller ratios travel more rapidly. Separation occurs as the ions travel down a field-free region, at the far end of which is located a detector that generates currents proportional to the quantities of ions.

We have designed and constructed a gas chromatograph which leads directly to the sample input of the mass spectrometer. Thus, mass spectra of the pure components of a mixture can be obtained at the same time they are separated.

Hydrocarbon Detector

This instrument, manufactured by Perkin Elmer Corporation, detects and measures total organic contaminants in the atmosphere. The

contaminants are detected by an internal hydrogen-flame ionization detector and the concentration indicated by a meter on the front panel. The hydrogen flame ionizes molecules containing hydrocarbon groupings, and these ionized particles are measured as an electrical current to a charged electrode. Since different classes of organic compounds have different detector responses, the meter indication for a given sample must be interpreted on the basis of instrument calibration with an appropriate test gas.

Auto Analyzer

The Technicon Auto Analyzer is an instrument which automates colorimetric chemical analysis. The center of the system is a peristaltic pump which can operate up to eight tubes from sample, diluent and reagent sources. The sample originates at a rotating plate where a movable crook picks up samples at the rate of 20, 40 or 60 a minute. After passage through the pump, diluents and reagents are added by joining tubes; separations are achieved by passage through a continuous dialyzer; and colorimetric reactions may be speeded up by a heating bath. The developed colored solution is directed into a continuously operating colorimeter which sends a signal proportional to percent transmittance to a recorder. Thus, all the operations of analytical colorimetry except sampling and data reduction are performed by this instrument.

Automatic Titrator

This is a compact instrument designed for titrations with automatic end points. It can be used with any available electrode combination for pH or potentiometric titrations. The control unit includes an accurate potentiometer provided with a temperature-compensating network, a null-sensing amplifier, and a circuit which anticipates the approaching end point to prevent overshooting. When the potential difference between electrodes approaches a predetermined value, an actuator starts to close the diaphragm valve controlling titrant flow and closes it completely at the end point.

Autoset Spectrophotometer

The Autoset Spectrophotometer is a single-beam spectrophotometer capable of operation through the spectral region of 200 - 1000 m μ . It features digital readouts of wavelength and of analytical data in terms of either transmittance or absorbance.

Tungsten and deuterium lamps supply light which is dispersed by a diffraction grating. Fixed entrance and exit slits provide a beam of constant 2 mμ bandwidth.

The beam passes through the cuvette compartment to strike the phototube whose output is directed to a servomechanism which, in turn, drives the digital readout.

Flame Photometer

The Coleman Model 21 Flame Photometer consists of a high intensity, direct atomizing oxy-gas burner, a photometer utilizing a phototube and preamplifier, a regulated power supply and sample lifter. An auxiliary indicating instrument is required which, in this case, is the Coleman Junior Spectrophotometer. Flame photometry is used for the routine analysis of sodium, potassium and calcium.

Auto-Dilutor

There are available in the laboratory three Auto-Dilutors. These are semiautomatic instruments for precise pipetting and diluting of small quantities of liquids in widely variable ratios. Liquid volumes are adjusted by means of micrometers. Increased accuracy, reproducibility and speed are obtained in many analytic procedures when the Auto-Dilutor is used. Its main use in the THRU laboratory is as a clinical chemistry tool when large numbers of samples must be processed.

Automatic Blood Cell Counter

Within the Coulter Counter, a suspension of cells in an electrically conductive medium is caused to flow through a minute aperture conducting an electric current between platinum electrodes. Each individual cell produces a voltage pulse of an amplitude proportional to its volume. Resulting pulses are displayed on the oscilloscope screen as distinct vertical spikes - relative cell size being indicated by the height of the spike. Simultaneously these pulses are fed to a threshold circuit allowing selection of sizes of cells to be counted. Unit counts up to 100,000 cells may be made in 15 seconds. With the instrument, total cell count or cell size distribution may be obtained with a 350% increase in accuracy in one-third the time of visual counts.

Hematocrit Centrifuge

The instrument is designed specifically for the determination of microhematocrit or packed red cell volume. It accepts the capillary tubes used in this measurement and runs at a constant speed. A timer switch turns the centrifuge on for periods up to 15 minutes and turns it off at the end of the programmed time.

EMERGENCY SAFETY EQUIPMENT

General

Emergency safety equipment has been provided for use in the THRU laboratory. This equipment is intended to be used for fire, contaminant spillage or accidental injury to personnel. In the event of fire, the domes containing gaseous oxygen are equipped with an automatic sprinkler system as well as a manual control within the domes for water deluge. Fire blankets and carbon-dioxide fire extinguishers have also been distributed throughout the area. Scott Air-Paks have been made available for contaminant spillage. A resuscitator-aspirator has been provided for emergency use when personnel have ceased to breathe. It is intended for use only until an ambulance arrives.

A special instrument has been provided for the treatment of cardiac arrest or ventricular fibrillation and may be used as an artificial pacemaker. This instrument, known as the Cardioverter, is intended for use by a physician only. A first aid kit and other emergency medical supplies have been provided for use by medical personnel.

Emergency lighting has been installed for the entire altitude facility in the event of power failure. This lighting system consists of nine pairs of seal beam lamps, operated by a 12-volt storage battery. The batteries are kept at full charge by a built-in trickle charger. The battery charging and switching on of lights is fully automatic. The lamps have been mounted in strategic places such as stairwells, airlock area and the control module area to provide maximum safety and lighting to personnel at the time of a power failure. The principle and operation of this system is that a microswitch energized by the 110-volt circuit switches to the battery circuit when building lighting is interrupted.

CRITICAL SPARE PARTS

A stock of difficult-to-obtain spare parts is maintained to insure minimum interruption of laboratory operations in the event of equipment

malfunction or failure. This inventory includes spare dome windows and gaskets, inflatable o-rings for the domes as well as replaceable parts or modules of the systems control and recording devices. This inventory of critical spare parts is currently being expanded as more information is obtained concerning the local availability of replacement parts which are considered essential to the operation of the THRU facility.

MAINTENANCE EQUIPMENT

A maintenance shop has been equipped for use by the THRU laboratory. A complete set of normal hand tools has been obtained, as well as a sabre saw and an electric drill. A grinder is currently being purchased. A jeweler's lathe was obtained to make small metal pieces for repair of laboratory equipment.

For maintenance work and repair of pneumatic instrumentation systems, a test stand has been built. This test stand enables the calibration and repair of pneumatic recorders to be conducted under actual operating conditions. In addition, voltmeters and a voltage calibrator have been obtained.

SECTION XVII

TRAINING PROGRAMS FOR PERSONNEL

ALTITUDE INDOCTRINATION COURSE

Before any employee is permitted to enter a dome which is under altitude conditions, he must satisfactorily pass a one and one-half day course given by the Physiological Training Section, Aerospace Medicine Division. This course introduces the future dome entrants to the geophysical, physiological and pathological aspects of high altitude flying. He is introduced to the effects that he may experience at reduced pressures and the necessity for denitrogenization and the breathing of oxygen. Part of the course includes exposure to altitude conditions in a specially constructed altitude chamber. Upon passing a written test, the trainee is presented with a card denoting satisfactory completion of the course. Upon receipt of the employee's card, the Laboratory Director gives that individual permission to enter the domes following sufficient on-the-job training.

ON-THE-JOB TRAINING

Upon satisfactory completion of the Altitude Indoctrination Course, the new employee is assigned to the Chief Chamber Technician who assumes responsibility for his future training.

If the new employee is not a Chamber Technician, he is supplied with a copy of Standard Operating Procedures for Thomas Domes, with which he is to become familiar. Subsequently, he spends several days as an additional observer during the periods of routine and general maintenance of the domes. If his eventual duties include periodic dome entrances, he is further trained by actually accompanying Chamber Technicians on their routine ascents to altitude until he is accustomed to the techniques and conditions involved.

If the new employee is a Chamber Technician, he is supplied not only with a copy of Standard Operating Procedures for Thomas Domes but also with copies of all other pertinent instructions such as are presented in the section of this report on Standard Operating Procedures. Not only is he expected to become familiar with the material, but he will subsequently be given a written examination upon which his future employment will depend. The employee is assigned to spend several days with each of the two observers and to become familiar with their duties. He then accompanies the dome entrant into the domes and assists him with the actual maintenance

work. After several such ascents with a trained Chamber Technician, he is permitted to enter the dome alone. Following such assignments, he is given the task of Observer B or Observer A but is still closely supervised. Only after the Chief Chamber Technician is satisfied that the new employee is thoroughly trained is he permitted to function as a regular Chamber Technician.

EMERGENCY PROCEDURE TRAINING

All Chamber Technicians are thoroughly trained in emergency procedures by means of written directions and by being personally conducted by the Chief Chamber Technician, step by step, through the correct emergency procedure for the particular situation concerned. The Chamber Technicians are refreshed in emergency procedures as frequently as routine operations permit.

Periodically and unannounced, an emergency situation is precipitated by the Chief Chamber Technician, and the Observer A on duty is graded according to his response, both as to adherence to the proper procedure and as to the rapidity with which he corrects the situation.

Unless an employee responds quickly and correctly to emergency situations, he cannot assume the responsibilities of a regular Chamber Technician and, therefore, he must correct his deficiencies or his services are terminated.

WEEKLY INFORMATION AND TRAINING MEETINGS

Each week the Chief Chamber Technician schedules a one-hour meeting with the Chamber Technicians. Either the Chief Chamber Technician or members of the other departments of the THRU present informal lectures followed by discussions on such topics as dome operation and maintenance, safety requirements, emergency procedures, contaminant generation and analysis, record-keeping and animal caretaking.

SECTION XVIII

SUMMARY

The Toxic Hazards Research Unit laboratory consists of an Ambient Pressure Laboratory which has a functional capability for conducting standard inhalation toxicity programs of acute or chronic nature on materials of Air Force interest.

The second major part of the facility is the Reduced Pressure Laboratory containing the four Thomas Domes. This Reduced Pressure Laboratory is a unique research facility of broad functional capability for toxicity testing programs. In this laboratory, continuous inhalation exposures can be provided for experimental animals at pressures ranging from 255 mm to 760 mm Hg. The internal environment of the chambers may consist of single or mixed gases to which contaminants may be added at controlled rates.

Research projects were initiated during the current report period in both of these facilities. In the Ambient Facility, chronic six-month inhalation exposures of animals to two concentrations of chlorobromomethane were conducted; and a separate toxicity report concerning this research has been prepared. Acute toxicity experiments were initiated using the pyrolysis products of chlorobromomethane and bromotrifluoromethane, two standard Air Force fire extinguishment compounds.

A series of tests were initiated during September of 1964 in the Reduced Pressure Laboratory. One dome was utilized to conduct a 90-day oxygen toxicity study at reduced pressure. This dome was also used to house control animals for two-week toxicity tests conducted in each of the other three domes. The two-week toxicity testing program consisted of continuous exposure both at reduced and ambient pressures to various concentrations of three specific test materials. The three test materials selected were of known toxicity and were selected to allow a comparison of the effects of equivalent toxicant levels at the two experimental parameters, namely reduced and ambient pressure. The agents selected were carbon tetrachloride, a known systemic toxicant; nitrogen dioxide, a primary irritant of the lung; and ozone, which is a primary lung irritant but has also been reported to produce systemic effect as shown by alteration of alkaline phosphatase activity. The studies are continuing and will be described in separate toxicity reports and in the subsequent annual report.

DOCUMENT CONTROL DATA - R&D

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1. ORIGINATING ACTIVITY (Corporate author) Aerojet-General Corporation PO Box 3067 Dayton, Ohio 45431		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP N/A	
3. REPORT TITLE TOXIC HAZARDS RESEARCH UNIT Design and Construction Phase			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) First of a series of annual reports, 1 June 1963 - 15 February 1965			
5. AUTHOR(S) (Last name, first name, initial) MacEwen, J. D.			
6. REPORT DATE September 1965		7a. TOTAL NO. OF PAGES 101	7b. NO. OF REFS None
8a. CONTRACT OR GRANT NO. AF 33(657)-11305 b. PROJECT NO 6302 c. Task No. 630201 d.		9a. ORIGINATOR'S REPORT NUMBER(S) Aerojet-General Corp Report No. 3024 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AMRL-TR-65-125	
10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC. Available, for sale to the public, from the Clearinghouse for Federal Scientific and Technical Information, CFSTI (formerly OTS), Sills Bldg, Springfield, Virginia 22151.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio	
13. ABSTRACT A facility was designed and constructed at Wright-Patterson Air Force Base for the specific purpose of conducting inhalation toxicology research. This facility is unique in that it has considerable functional variability and may be used for the study of space cabin toxicity under altitude and 100% oxygen conditions. Additionally, the laboratory was designed for use as a standard inhalation toxicology laboratory for the study of Air Force materials which may constitute a hazard to ground support personnel. This report describes the design and functional capability of the Toxic Hazards Research Unit laboratory which became operational in September of 1964. Toxicology research of the nature described has been initiated and will be reported upon as individual experiments are completed.			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Toxicity Hazards laboratory Instrumentation Medical research Atmosphere monitoring Contamination Liquid oxygen equipment Training Physiology						

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